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HARTIGAN'S ILLUSTRATED TEXT-BOOK FOR SCHOOLS.

ANATOMY,

PHYSIOLOGY, AND HYGIENE,

WITH

THE EFFECTS OF ALCOHOL AND NARCOTICS ON THE HUMAN BODY.

BY

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PREFACE.

THE preparation of this work was undertaken at the instance of the Author's many friends and a number of prominent teachers. It is designed to supply the need of a suitable text-book that shall meet the requirements of recently-amended School laws relative to the teaching of the subjects of Anatomy, Physiology, and Hygiene in the Public Schools. In this the aim of the Author has been directed to the restriction of his treatise on these subjects within the limits of a single volume, so as to fully cover every material point, as well as to avoid the usual heavy expense which a series of two or three books on the same subjects entails upon the student.

The arrangement of the work is a departure from the plan generally followed in books of a like character, in that it is comparative, giving the pupil more comprehensive views of the subjects treated and enabling him to grasp them more readily. Special attention has also been given to the preparation of the questions to the respective chapters, with the view of greatly simplifying the matter for both teacher and pupil.

The illustrations are from drawings by Mr. Christian

Kaiser, of Cologne, Germany, taken from models and dissections made by the Author in the dissecting-rooms of the West Virginia University. By special permission of Prof. Joseph D. Bryant, of the Bellevue Hospital Medical College, the Author has been enabled to give a Table of the Muscles of the Human Body, the arrangement of which is, with few exceptions, the same as that followed by that distinguished author and teacher in his "Series of Muscle Tablets."

The Author also acknowledges his indebtedness to the Rev. W. R. White for his excellent and able article on "The Intemperate Use of Alcohol;" and to the publishers, Messrs. John E. Potter & Company, of Philadelphia, who have spared neither labor nor expense in the proper and effective execution of the work.

JAMES W. HARTIGAN.

WEST VIRGINIA UNIVERSITY, *August*, 1890.

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Anatomy, Physiology, and Hygiene.

CHAPTER I.

THE BLOOD.

SECTION I.

1. *Definition.*—Blood is a liquid tissue. It is the most important of all the fluids of the body. It contains food in solution for all parts, and receives from the tissues the effete, poisonous matter which is produced by their action.

2. There are a great many kinds of blood to be found in the different divisions of the animal kingdom. But any fluid which has for its work or function the regeneration of animal tissues may properly be called blood.

3. In many of the lower forms of life the blood is a very simple and colorless fluid, containing only a few granules of organic matter, with inorganic salts in solution. In the first forms of life this simple fluid furnishes all the food that is necessary for the growth and development of all the tissues and organs of which these lowly-organized creatures are composed. It also contains all the products of physiological activity—secretions and

excretions, as well as air in solution for respiration. As yet there is no elaboration of parts or differentiation of structure for the performance of multiplied function.

4. If we continue our study of this branch of organic life, we notice a change taking place in the tissues of the body, certain parts becoming peculiarly modified and specialized for the performance of certain functions, until we reach the wonderful structure of man, presenting the complex apparatus for locomotion—bones and muscles; a muscular pump for throwing blood to all parts of the body—the heart; special organs for secretions and excretions—the liver, kidneys, lungs, salivary and mammary glands, as well as the various glands connected with the alimentary and genito-urinary tracts.

5. Now, as the structure of the bodies of animals becomes more complex, so the blood changes in its structure from, at first, a simple colorless granular fluid, until in the higher vertebrates and in man we find the great vital fluid red in color and composed of many anatomical elements. The quantity of blood in the human body is from one-tenth to one-eighth of the weight, or from sixteen to twenty pounds.

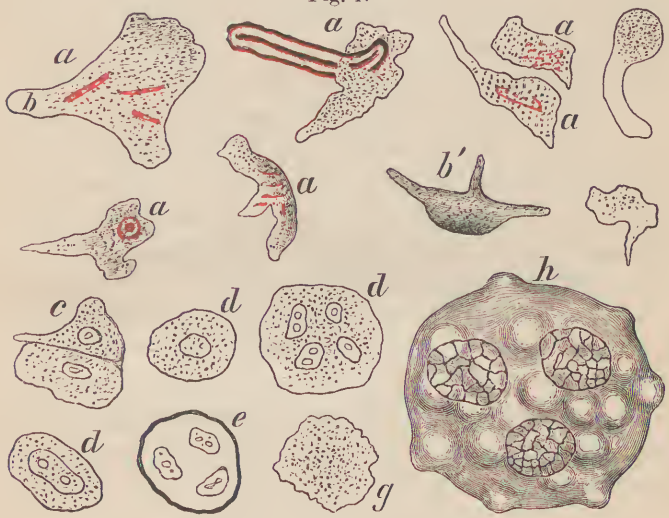
SECTION II.

ANATOMY OF THE BLOOD.

1. The blood is composed of two distinct parts—a liquid part and a semi-solid part. The fluid portion of the blood is called the *liquor sanguinis* or *plasma*, and floating in this are the cellular or corpuscular elements (Fig. 1).

2. **Plasma.**—The plasma is the clear fluid part of the blood. It contains, in solution, all the proximate principles in a condition to be used by the tissues, and can be divided into a liquid portion called *serum* and a solid part called *fibrin*. The serum is the plasma deprived

Fig. 1.



WHITE BLOOD-CELLS.

a, a, a, a, a, a, "phagocytes," white cells containing micro-organisms; *b, Bacillus tuberculosis,* the organism causing consumption or phthisis; *b′,* white cell showing pseudopodia; *c,* same, showing process of reproduction by division; *d, d, d,* the appearance of white blood-cells after the addition of water; *e,* same, after addition of dilute acetic acid; in *c, d, e* the nuclei are visible; *g,* normal appearance of a white blood-cell; *h,* after the action of dilute alcohol.

of the fibrin factors; it is not a natural constituent of the blood, being formed only after the blood is drawn from the body.

3. **Fibrin** is the name given to the solid portion of a blood-clot, and is composed of two factors, which are

called *fibrinogen* and *fibrino-plastin* or *paraglobulin*. While the blood is moving or circulating in the vessels of the body these factors do not combine; but when the blood is allowed to flow from a cut vessel they come together and form a fibrillated or stringy substance, which soon contracts into a jelly-like mass which is called fibrin, holding in its threads or meshes the corpuscles of the blood, and squeezing out or expressing a clear or straw-colored liquid, which is the serum.

4. The fibrin and corpuscles constitute the clot, while the serum is all the liquid part of the plasma. This natural formation of a clot performs an important function in the arrest of hemorrhage. Were it not for this provision of nature, we would bleed to death whenever a vessel of any size became ruptured.

5. The plasma, in man, forms a little more than one-half of the whole volume of blood—exactly sixty-four parts of plasma and thirty-six parts of corpuscles in one hundred volumes. The plasma is heavier than water, having a specific gravity of 1028, and its reaction is alkaline.

SECTION III.

BLOOD-CELLS OR BLOOD-CORPUSCLES.

1. A variety of names is given to the semi-solid constituents of the blood. They are called blood-cells, blood-disks, blood-globules, and blood-corpuscles—all meaning the little round or ovoid bodies which swim about in the plasma.

2. In all vertebrates (animals possessing backbones)

the plasma contains at least two kinds of blood-corpuscles, which differ in size, and especially in color. They are called colored and colorless, or red and white blood-cells.

3. In the higher vertebrates—viz. mammals, to which class man belongs—there exists a third corpuscle, which is now considered a constant element of mammalian blood. These corpuscles are sometimes called *hæmatoblasts*, but the name now generally accepted is *blood-plates* or *blood-plaques*. They are small and colorless, increase in number in certain diseases, and are thought to have something to do in causing the coagulation of the blood (Fig. 1).

4. There also exist in the blood—in considerable numbers after a meal or during digestion, few in number during the intervals of digestion—small granules, called by some writers *elementary granules*, by some *globulins:* they are probably fatty in their nature, and are derived from the chyle.

SECTION IV.

RED BLOOD-GLOBULES.

1. The red disks are the most numerous of all the cellular elements of the blood; they are also smaller than the ordinary white corpuscles. The whole number of red globules in the blood is enormous: various estimates have been made by different anatomists. One cubic millimetre (1 m. m.=$\frac{1}{25}$ in.) contains from 3,000,000 to 6,000,000. Power states that if all the red

corpuscles of the blood of an adult were put side by side, they would cover a surface of 3000 square yards. They vary in size from $\frac{1}{3200}$ to $\frac{1}{3600}$ of an inch in diameter, and from $\frac{1}{8000}$ to $\frac{1}{12000}$ of an inch in thickness. They are homogeneous in their structure, and are not provided with a nucleus; no membrane invests them.

2. In having no nucleus they differ from the white globules. They are biconcave in shape, and thinner in the centre than at the circumference. This fact causes them to present a peculiar appearance when examined with the microscope. Being thinner in the centre than at the periphery, both parts cannot be in focus at the same moment; hence when the centre is light the periphery is dark, and *vice versa*. Though called "red corpuscles," they only appear red when they exist in great numbers. When viewed singly in the plasma they have a yellowish-green color, the yellow color being more marked in arterial blood, the greenish hue predominating in venous blood. They possess some elasticity, and if deformed by pressure, as sometimes happens in passing through small capillaries, they rapidly regain their spherical shape. They also have the peculiar property of arranging themselves in rows resembling *rouleaux* of coin. This is due to the exudation of a sticky substance on their surface which causes them to adhere to each other when they come in contact. This is a *post-mortem* change, and does not occur while the blood is circulating in the vessels of the body.

3. If water be added to a specimen of blood, thereby diminishing the density of the plasma, the red blood-cells change their shape, swell up, and finally disappear. If the density of the plasma be increased, as by the

addition of a solution of sulphate of sodium, the corpuscles become contracted, shrink, and present a wavy or zigzag outline, returning to their normal shape if the proper density of the plasma be restored.

4. The **color** of the red cells is due to the presence of a coloring matter called *hæmoglobin*, sometimes called *hæmoglobulin* and *hæmotocrystalline*. This coloring matter has a great affinity for oxygen, and is important to remember in connection with the part the red corpuscles play in respiration. It can be separated from the blood as beautiful crystals which vary in shape in different animals.

5. The red blood-cells of all vertebrates below mammals—*i. e.* fishes, amphibians, reptiles, and birds—contain a nucleus and are oval or angular in shape, and instead of being biconcave are biconvex.

6. In healthy human blood there exists from six hundred to twelve hundred red corpuscles for every white one. The red cells are heavier than the plasma in which they float, their specific gravity being 1088 to 1105.

7. Their **origin** is not accurately known. They are supposed by some to be formed from certain marrow-cells of bone; by others from the blood-plaques or white cells; and some think they originate *de novo* in the plasma in which they swim. A relation is thought to exist between the size of the corpuscles and the activity of the animal—the smaller the corpuscle the more inactive the animal. There are many exceptions to this, but the higher we go in the animal scale the smaller the corpuscles, being smallest in mammals and largest in low orders of reptiles.

8. The following are the diameters of the red blood-corpuscles of some of the vertebrates (taken from Gulliver and Welcker): Man, $\frac{1}{3200}$; dog, $\frac{1}{3300}$; cat, $\frac{1}{4000}$; sheep, $\frac{1}{5000}$; elephant, $\frac{1}{2745}$; horse, $\frac{1}{4600}$; musk-deer, $\frac{1}{12325}$; pigeon, $\frac{1}{2317}$; toad, $\frac{1}{1043}$; newt, $\frac{1}{814}$; proteus, $\frac{1}{400}$ to $\frac{1}{250}$; pike, $\frac{1}{2000}$; shark, $\frac{1}{1142}$; mouse, $\frac{1}{3814}$; black rat, $\frac{1}{3754}$; brown rat, $\frac{1}{3911}$; ferret, $\frac{1}{4134}$; camel (oval), long diameter, $\frac{1}{3123}$, short diameter, $\frac{1}{5876}$; dromedary (oval), long diameter, $\frac{1}{3254}$, short diameter, $\frac{1}{5952}$; Virginia deer, $\frac{1}{5036}$.

SECTION V.

WHITE BLOOD-GLOBULES.

1. The **white corpuscles** of the blood of man are larger than the red, measuring from $\frac{1}{2000}$ to $\frac{1}{2500}$ of an inch in diameter. They are composed of an albuminous substance called *protoplasm*, which is transparent and sometimes granular, containing a clearly-defined central part called the *nucleus*, and not limited by a surrounding membrane (Fig. 1).

2. The corpuscles have the peculiar power of sending out from their surface small prolongations called *pseudopodia* or *false feet*, by which they are enabled to change not only their shape, but their position as well. This movement of the white corpuscles very much resembles the motion exhibited by certain low forms of animal life called *amœba*, and is called the *amœboid movement* of the colorless corpuscles, the word *amœba* meaning "to change."

3. The white corpuscles exist in the blood in the

proportion of one white to every six hundred to twelve hundred red ones. They greatly increase in numbers during digestion and rapidly diminish during the intervals of digestion. They are much lighter than the red blood-cells, and are generally found occupying the surface of the clot when blood is permitted to coagulate slowly, helping to form the so-called buffy coat. They have a specific gravity of 1070.

4. A white blood-globule often contains more than one nucleus, and sometimes its granular matter is (in the blood of some animals, especially the horse) of a reddish color; which fact has led some writers to think that these corpuscles represent a transitional stage between the white and red blood-cells.

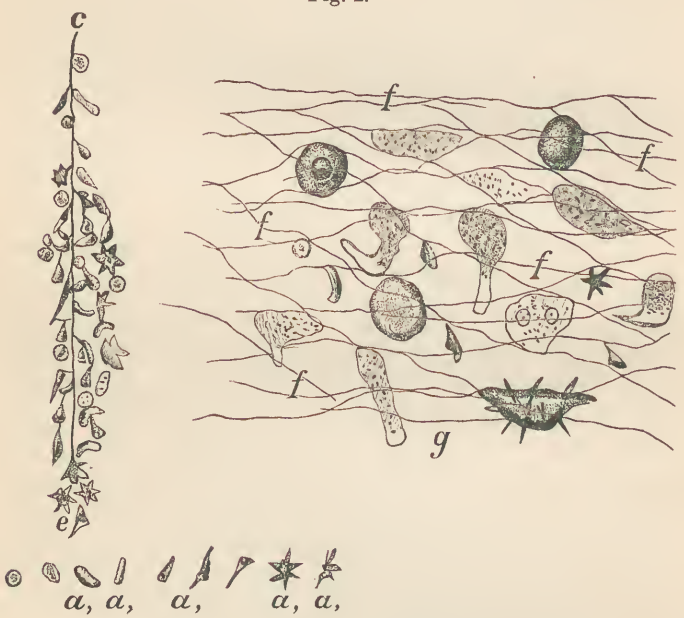
5. The function of the white blood-cells is not known. They have the power, by their amœboid movement, to penetrate the blood-vessels and gain access to the surrounding tissues. This occurs to a very considerable extent whenever any part of the body is injured, and they are probably concerned in the process of repair. They behave in a very peculiar manner within the blood-vessels, and if the circulation in the web of a frog's foot or in its tongue be examined with a microscope, they seem to be sticky, to adhere to each other and to the sides of the blood-vessel, moving much slower than the red corpuscles, which occupy the centre of the vessel and glide smoothly and rapidly along. The white blood-cells are now considered to be identical with those cells found in the lymph, chyle, pus, mucus, and colostrum. The addition of acetic acid will make the nucleus more pronounced.

SECTION VI.

BLOOD-PLAQUES AND ELEMENTARY GRANULES.

1. Constantly occurring in the blood of mammals are the third blood-corpuscles or **blood-plaques**, now regarded as a normal constituent of mammalian blood.

Fig. 2.



BLOOD-PLAQUES AND RAPID FORMATION OF CLOT.

a, a, a, a, a, blood-plaques of various shapes; *c, e,* thread holding numbers of blood-plaques, obtained by suspending thread in blood; *g,* shows formation of clot; *f,* strings of fibrin entangling in its meshes red and white blood-cells and blood-plaques.

They are from $\frac{1}{10500}$ to $\frac{1}{6400}$ of an inch in diameter, structureless, and without color, containing a few gran-

ules, but probably not a nucleus, properly so called. They increase in numbers during many diseases, and are thought by Bizzozero to furnish the ferment which brings together the fibrin-factors to form a *coagulum*, or clot (Fig. 2).

2. **Elementary granules**, called also *granules* and *globulins*, are supposed to be fatty particles derived from the chyle. They are not normal constituents of the blood, and are of no known physiological importance.

SECTION VII.

PHYSICAL CHARACTERS OF THE BLOOD.

1. The **density** of the blood varies somewhat within the limits of health according to the amount and kind of food taken. It also varies with the digestive act, and is greater in the male than in the female. The specific gravity of the blood at 60° F. is from 1052 to 1057.

2. The **temperature** of the blood also varies in different parts of the venous and arterial systems, being higher in the deep-seated tissues than in those near the surface. The average is given at from 98° to 100° F.—exactly, 98.6°. It is highest in the blood coming from the liver, where it is from 101° to 108°. The temperature of the blood is greater in birds than in any other animals, reaching as high as 112°.

3. The blood has a very faint and peculiar odor, which is said to distinctly resemble that of the animal from which it is taken upon the addition of a small quantity of sulphuric acid. The plasma or liquid portion of the blood normally contains a small quantity of

common salt (*chloride of sodium*), three to four parts in one thousand, which gives it a salty or saline taste. Its reaction is alkaline.

4. The **corpuscular portion** of the blood is transparent, as well as the plasma, but when they exist together, as they do when circulating under normal conditions in the circulatory system, they give rise to a fluid which has a density greater than the plasma and less than the corpuscles. When a ray of light enters a specimen of blood it is refracted or broken as it passes through the plasma; then, entering a corpuscle—which has a greater density than the plasma—it is broken again and at a different angle; and so on, until finally it is lost. This is what causes the *opacity* of the blood.

5. A thin layer of blood is transparent, having a slight yellowish-green tinge.

6. In the **arteries** the blood is bright red; in the veins it is dark-blue or black. It changes its color in the capillaries of the system, losing oxygen and gaining carbonic acid gas; again, in the capillaries of the lungs losing carbonic acid gas and gaining oxygen.

7. The **red color** in the arterial system is due to the presence of oxygen gas combined with the coloring matter of the red cells (*hæmoglobin*). The dark-blue or black color of venous blood is due to the presence of carbonic acid gas.

8. Under normal conditions of circulation and respiration the blood parts with its carbonic acid gas in the lungs and gains oxygen, changing from black, impure, or venous blood to red, pure, arterial blood. It then goes to the left side of the heart, and is pumped to all the tissues and organs of the body, changing from

pure, red, arterial blood to black, impure, or venous blood. It is then taken up by the veins and carried to the right side of the heart, thence to the lungs to be purified again, and made ready for another circuit of the body.

9. It sometimes happens that more arterial blood is sent to an organ than is necessary for the performance of its function. When this occurs all of the oxygen is not used by the tissues, and the blood in the veins returning from such a part is red. This takes place during the maximum activity of those glands which are concerned in the production of secretions and excretions.

10. **Coagulation.**—Where blood escapes from the body and comes in contact with the air it *coagulates* or sets into a jelly-like mass, forming a clot. When contraction of the *fibrin* has fully taken place, a liquid will be found squeezed out and occupying a position above the clot or solid part. The liquid is the *serum*, and is of a pale straw color; the solid part is the clot or *crassamentum*, and is composed of the fibrin and corpuscles (Fig. 3).

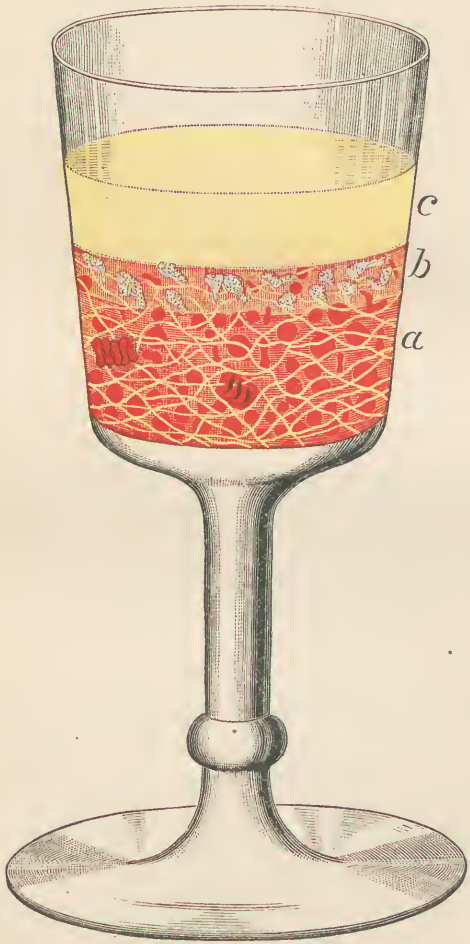
11. When **coagulation** has taken place slowly, the red blood-cells will be found in greatest numbers near the bottom of the clot, being heavier than the white cells, which are found in greatest numbers near the surface. When coagulation has been rapid, and the red cells have not had time to fall to the bottom, both red and white cells are found in all parts of the clot.

12. When coagulation has been slow, the clot will be firm; when it has been rapid, the clot will be soft.

13. That part of a **venous clot** which is exposed to

the action of the air is red, the central part being dark.

Fig. 3.



Designed to show the phenomena of coagulation: *a*, fibrin with heavy red cells in its meshes; *b*, buffy coat containing mostly white cells; *c*, expressed serum.

If the clot be divided by splitting it with a knife, a red blush will rapidly spread over the dark surfaces. This is due to the action of the oxygen of the air, driving out the carbonic acid gas and uniting with the coloring matter of the red cells.

14. Coagulation may be *retarded* by allowing the blood to flow into a smooth vessel containing one-seventh of its volume of a solution of sulphate of soda. It may be *hastened* by allowing it to flow into a vessel with rough surfaces, or into one containing bundles of small twigs or masses of thread. Coagulation takes place sometimes during life within the blood-vessels, but it is not a normal condition.

QUESTIONS.

SECTION I.

What is blood? What does it contain for the body? What does it receive from the tissues? How is this effete matter produced?(1). Are there many kinds of blood in the animal kingdom? What properties will give to a fluid the name of blood?(2). What kind of a fluid is the blood of the lowest animals? What does this simple fluid contain?(3). Is there a gradual increase in the complexity of the structure of animals from the lowest to the highest? What kind of apparatus has man for locomotion? circulation? secretion and excretion?(4). Does the blood change in structure and complexity with the body of the animal? What kind of blood is found in the higher vertebrates and in man? What is the quantity of blood in the human body?(5).

SECTION II.

Of how many parts is the blood composed? What are they? What is the fluid part called? What is the semi-solid part called?(1). What is the plasma? What does it contain? Into how many parts can it be divided? What are they? What is the serum? Is it a natural con-

stituent of the blood? When is it formed?(2). What is fibrin? Of how many factors is it composed? What are those factors called? Do they come together while the blood is circulating in the vessels of the body? When do they unite? By their union what do they form? Does this fibrillated substance contract? What kind of a mass does it form? What does it entangle in its meshes? What kind of a liquid does it squeeze out? What is the name of this liquid?(3). What constitutes a clot? What is the liquid part of the plasma called? Does the formation of a clot prevent continued hemorrhage?(4). What proportion of the volume of blood does the plasma form in man? Is it heavier or lighter than water? What is its specific gravity? What is its reaction?(5).

SECTION III.

What names are given to the semi-solid constituents of the blood? What do these names all mean?(1). How many kinds of corpuscles are found in the blood of back-boned animals? Do they differ in size and color? What are they called?(2). To which class of vertebrates does man belong? Does the blood of mammals contain more than two kinds of corpuscles? What are these third blood-corpuscles called? Under what conditions do they increase? Do they play any part in causing the blood to coagulate?(3). Are there any other formed bodies in the blood in addition to those mentioned? When are they increased as regards the digestive act? when diminished? What is their nature? their probable source?(4).

SECTION IV.

Which are the most numerous of the cellular elements of the blood? Are they larger or smaller than the white blood-cells? What can you say of their number? How many are in one cubic millimetre? What part of an inch is a millimetre? If all the red blood-cells of an adult were put side by side, how much surface would they cover? What is their diameter? Their thickness? What can you say of their structure? Have they a nucleus? Are they invested by a membrane?(1). How do they differ from the white blood-cells? What is their shape? Where are they thinnest? Can periphery and centre be in focus at the same time? What appearance does this produce? What is their color in a thin layer? When are they red? What color predominates in arterial blood? in venous blood? Do they possess elasticity? If deformed, do they regain their shape under normal conditions of circula-

tion? To what is their rouleaux arrangement due? Does this occur while the blood is circulating in the vessels?(2). When water is added to the blood, what is the effect on the red blood-cells? If the plasma be rendered dense by the addition of some salt, what is the effect on the red blood-cells? How can their normal shape be restored?(3). To what is the red color of the red cells due? Has this coloring matter an affinity for oxygen? Can it be separated from the blood? Do the crystals vary in shape in different animals?(4). What is the character of the red blood-cells in the vertebrates lower than mammals? Why are they biconvex?(5). What is the relative number of red and white blood-cells in healthy human blood? What is the weight of the red cells as compared with the plasma? What is their specific gravity?(6). What is the origin of the red cells? Give some supposed sources of the red blood-cells? Is there any relation between the size of the red corpuscle and the activity of the animal? How does this rule hold when applied to animals high and low in the scale of life?(7). Give some diameters of red blood-cells in different animals?(8).

SECTION V.

What is the size of the white blood-cells in man? What is their shape when at rest? Of what are they composed? Do they contain a nucleus? Are they surrounded by a membrane?(1). What peculiar power is possessed by the white corpuscles? What enables them to change shape and position? What is meant by the amœboid movement of the white blood-cells? What does the word "amœba" mean?(2). In what relative number to the red cells do the white cells exist in the blood? When do they increase in numbers? When do they diminish? Are they heavier or lighter than the red cells? In what part of the clot are they generally found? What is their specific gravity?(3). Do the white cells ever contain more than one nucleus? Is their granular matter ever colored? What are those white cells whose granular matter is colored supposed, by some, to represent?(4). What is the function of the white blood-cells? Have they the power to penetrate the vessels? When does this occur? Are they concerned in the repair of injured tissues? How do they behave within the lumen of the blood-vessels? What part of the lumen of the vessel is occupied by the red cells? How do they move? How do the white cells differ from those found in the lymph, pus, chyle, mucus, and colostrum? What is the action of acetic acid on the white blood-corpuscles?(5).

SECTION VI.

Are the blood-plaques regarded as normal constituents of mammalian blood? What is their diameter? What is their structure? Have they a nucleus? Under what conditions are they increased in numbers? What is Bizzozero's theory of their function?(1). What are the elementary granules supposed to be? Are they normal constituents of the blood? What is their function?(2).

SECTION VII.

What causes the variation of the density of blood? Is it greater in the male or in the female? What is its specific gravity?(1). Does the blood vary in temperature in different divisions of the vascular system? Is it higher in superficial or deep-seated tissues? What is the average temperature of the blood? In what animals does the blood reach the highest temperature?(2). What is peculiar about the odor of blood? How may it be developed? What is the reaction of the blood?(3). Is the corpuscular portion of the blood opaque or transparent? What makes the normal circulating fluid opaque?(4). What is the character of a very thin layer of blood?(5). What is the color of blood in the arteries? in the veins? Where does it change its red color? What gas does it lose? What gas does it gain? Where does it lose its black or dark-blue color? What gas does it lose? What gas does it gain?(6). To what is the red color in the arterial system due? To what is the dark color of venous blood due?(7). Trace the current of blood and describe its changes from the right side of the heart to the point of starting?(8). Is there ever more arterial blood sent to an organ than is necessary? When this takes place, what is the color of the blood in the returning veins of that organ? When does this take place? In what glands does it generally occur?(9). What change takes place in blood when it escapes from the vessels and comes in contact with the air? After contraction of the fibrin what kind of a liquid is found above the clot? What is the color of the serum? Of what is the clot composed?(10). In what part of a slowly-forming clot will the red cells be found? When the formation has been rapid, where will they be found? Why? Where are the white cells found in a slowly-formed clot? Where in a clot of rapid formation?(11). Under what conditions will a clot be firm?(12). What is the color of that portion of a venous clot which is exposed to the air? What is the color of the central part? If the clot be divided, what causes the change of color of the central part?(13). How may coagulation be retarded? How hastened? Does coagulation take place within the vessels during life? Is it a normal condition?(14).

CHAPTER II.

PHYSIOLOGY OF THE BLOOD.

SECTION I.

1. The office of the blood is to supply all tissues and organs of the body with food for their growth and for the performance of their functions. The tissues and organs—with a few exceptions, as the enamel of the teeth, the nails, hair, and *epithelium*—are supplied with vessels through which the blood is pumped by the heart to all parts (**arteries**); another set of very fine vessels (**capillaries**), whose function is to distribute to the tissues the blood pumped by the heart through the arteries; and still another set (**veins**) whose work is to carry the blood back again to the right side of the heart, preparatory to its being sent to the lungs for purification.

2. The **passage** of the blood from the left side of the heart through the system—arteries, capillaries, and veins—to the right side is called the *greater* or **systemic** circulation; the passage of the blood from the right side of the heart through the lungs to the left side is called the *lesser* or **pulmonary** circulation.

3. The plasma or liquid portion of the blood, sometimes called the *liquor sanguinis*, is the *menstruum* or *matrix* in which the corpuscles float. It contains, prin-

cipally, the food for the tissues, as well as certain worn-out, effete materials—ash—which are formed by tissue-activity or tissue-work. The food-materials exist in greater quantity in the arterial division of the vascular system; the effete, ashy matter predominating in the veins.

4. **Colored Corpuscles.**—The red cells of the blood carry oxygen to the tissues from the lungs, the tissues being unable to perform their work in the absence of this gas. They take the oxygen from the red blood-cells, and give up another gas—carbonic acid gas—which acts as a poison in the absence of oxygen, and causes the blood to change in color from red to dark-blue or black.

5. These important changes—loss of oxygen and gain of carbonic acid gas, and change from pure to impure blood—take place in the region of the small vessels which connect the arteries with the veins, called the capillaries. These vessels have but one very thin coat.

SECTION II.

WHITE BLOOD-CELLS.

1. The **function** of the *leucocytes*, or white blood-cells, is not exactly known. They are supposed by some writers to break up and form nuclei or kernels about which red cells form. They are probably concerned sometimes in the formation of new tissues, as when divided parts heal and become united. They are of importance in furnishing a principle—**ferment**—which assists in the coagulation of blood. They are also con-

cerned in the destruction of tissues under certain conditions, as when animals lose some of their parts by gradual decay—*atrophy*—pieces of tissue having been recognized in their interior.

2. They probably perform an important service for the body in the destruction of certain *micro-organisms* (microscopical plants) which exist in the blood in great numbers in certain diseases, as pneumonia, cholera, typhoid fever, consumption (*tuberculosis*), erysipelas. Those white cells which feed upon these organisms have been called *phagocytes* or eating cells (Fig. 1).

3. **Blood-Plaques.** — Physiologists have no exact knowledge of the function of the blood-plaques. They are supposed by some to be nuclei for red blood-cells; by others to be formed from the disintegration of white blood-cells, therefore fragments of leucocytes; and by still others to be formed *de novo* from the plasma. They increase in numbers during pregnancy and whenever blood is rapidly formed in quantity (Fig. 2).

4. If we would have healthy tissues and organs, sound bodies, and perfect health, it is absolutely necessary that we have good nutritious blood, and that all the material, as well as organs concerned in its formation and distribution, should be healthy in structure and perform their functions properly. A stomach which has its mucous membrane eaten into ulcers by the use of alcohol cannot secrete a healthy gastric juice for digestion; a liver contracted and hardened by the use of intoxicating liquids cannot furnish healthy bile; and a heart under the influence of alcohol does not properly distribute the blood.

5. Another important function of the blood is to

take up effete matter wherever it finds it in the tissues, and carry it to the various excretory organs—the kidneys, liver, lungs, skin, and alimentary canal (though the liver, lungs, skin, and alimentary canal also have other functions)—whose work is to separate the poisonous matter from the blood and put it in a condition to be discharged into the external world.

SECTION III.

ACTION OF ALCOHOL AND NARCOTICS ON FRESHLY-DRAWN BLOOD.

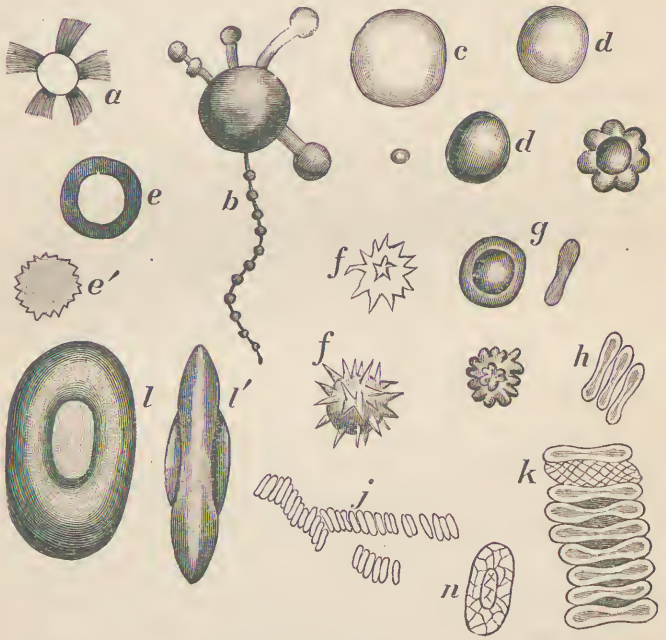
1. The **red blood-cells** are said by many authors to be *increased* in size in the body by the free use of alcohol. A number of other substances produce the same effect, as cold, oxygen, quinine, and the poor condition of the blood during many diseases.

2. The habitual use of **morphia** (the active principle of opium), fevers produced by the absorption of septic matters, violent exercise, and starvation cause the red blood-cells to become *diminished* in size.

3. When **alcohol** is added to a fresh specimen of blood on a glass slide, and examined with a microscope, a very small quantity of dilute alcohol causes the red blood-cells to appear larger, smooth, and to arrange themselves edge to edge; that is, they touch at some part of their circumference, and do not present the characteristic arrangement like piles of coin with their flat surfaces touching. Acted upon by a stronger solution of alcohol, they become distinctly smaller, have an irregular wavy or zigzag appearance, and tend to

aggregate in masses, still showing the tendency, however, to come together at their edges instead of at their flat surfaces. This irregular appearance of their circumference may be due to the abstraction of some of the water of the cell by the alcohol (Fig. 4).

Fig. 4.



RED BLOOD-CELLS.

a, effect produced by addition of ether to specimen of fresh blood; *b*, appearance caused by chloral hydrate; *c*, appearance produced by action of cocaine; *d*, *d*, effect produced by action of opium; *e*, effect produced by rapid drying; *e′*, crenation by loss of water: *f*, *f*, effect of strong alcohol; *g*, normal appearance, surface view; *h*, side view; *j*, coin-like arrangement; *k*, exudation holding them together; *l*, corpuscle of a frog; *l′*, edge view; *n*, stroma of same.

4. **Opium.**—A strong alcoholic extract of opium

causes the red blood-cells to become rather dark and of a round, homogeneous, smooth appearance. They do not arrange themselves in piles like *rouleaux* of coin, and all over the field may be seen great numbers of very small circular bodies resembling blood-plaques, with multitudes of small granules arranged in masses. Occasionally, under treatment with opium, a few of the red cells are irregular in outline, but this is probably caused by the alcohol used or by evaporation (Fig. 4).

5. **Chloral.**—A concentrated watery solution of hydrate of chloral causes the red cells to break up, and they never arrange in piles with their flat surfaces touching. Numerous small globular buds are seen to develop on their surface, and often these buds are attached to each other like beads on a string. They may form chain-like strings, or break apart and exist as very small round bodies in masses (Fig. 4).

6. **Cocaine.**—Acted upon by a strong aqueous solution of cocaine (active alkaloid of *Erythrox'ylon co'ca*), the red blood-cells become dissolved, only a very few being seen in the field, and these are clear, with a faint and indistinct outline (Fig. 4).

The plant which furnishes cocaine grows on the eastern slopes of the Andes Mountains, and is used by the inhabitants of Bolivia, Chili, and Peru as an article of diet and as a medicine. It takes the place of the coffee, tea, opium, and hashish of other peoples. Recently it has been much used as a local application to prevent pain during minor operations in surgery. When habitually used for the pleasure of the effect it produces, it leads to the formation of a habit more terrible than

that of opium or alcohol, completely depriving its victim of his higher intellectual faculties and judgment, and ending oftentimes in murder and suicide.

7. **Tobacco and its Active Principle, Nicotia.**—Strong solutions of tobacco have no perceptible influence on the shape or size of the blood-cells, red or white. Its active principle, *nicotia*, causes the blood to become dark in color and the red cells to disintegrate.

8. **White Blood-Cells.**—Dilute alcohol causes the white blood-cells to become clear (making the nucleus more prominent), to develop little bladders or vesicles on their surface, and, in greater strength, to become dissolved (Fig. 1).

9. **Quinine** (*Quininæ Sulphas*) arrests their movements and prevents them from passing through the walls of the small blood-vessels. Induced currents of electricity also arrest their movements, and, if too strong or oft repeated, finally kills them.

10. Alcohol in some form has been employed as a dressing for wounds and ulcers since the earliest times in the history of surgery. As used by the ancients, it was in the form of wine with some astringent. In its most popular form now it is used as the camphorated spirit of wine, and is thought by many eminent surgeons to be the best of all dressing for wounds and ulcers. Its efficacy is in proportion to the alcohol it contains.

11. **History.**—Leeuwenhoek first saw the red cells of human blood in 1673. He described them in a paper published in 1674. Red blood-cells had been seen, however, before this by Malpighi in 1661, while examining the blood of a hedgehog. William Hewson described the white blood-cells or leucocytes in 1774.

TABLE SHOWING THE CONSTITUENTS OF BLOOD.

- **Blood.**
  - Corpuscles.....
    - Red,
    - White,
    - Blood-Plaques,
    - Granules.
  - Liquor sanguinis or Plasma.
    - Fibrin.
      - Fibringen,
      - Fibrinoplastin, or Paraglobulin,
      - Ferment,
    - Serum.
      - Serine,
      - Metalbumen,
      - Water.
  - Clot.
    - Fibrin,
    - Corpuscles, and
    - generally $\frac{1}{5}$ of the Serum.

QUESTIONS.

SECTION I.

What is the function of the blood? How is the blood brought to the tissues? Name some structures that are not supplied with vessels. What sends the blood to the tissues? What is the function of the capillaries? the veins? Where do the veins carry the blood? Why is it sent from the right side of the heart to the lungs?(1). What is the greater circulation? Give both circulations, beginning with the right side of the heart.(2). What is the plasma? What does it contain? What part of the vascular system contains the most nutritive blood? In which division is the effete matter principally found?(3). What do the red blood-cells carry from the lungs to the tissues? Is oxygen necessary for tissue-work? What gas is produced by tissue-waste? Is carbonic acid gas (CO_2) poisonous in the absence of oxygen? What change in color does it produce in the blood?(4). In what division of the vascular system does this important interchange of gases take place? How many coats have capillaries?(5).

SECTION II.

What is the function of the leucocytes? Name some theories advanced as to their use. Do they assist in the coagulation of the blood?

Are they concerned in tissue-formation and tissue-waste ?(1). Do they probably feed upon organisms which produce disease ? Name some disease caused by micro-organisms. What special name have these bacteria-eating white blood-cells been given ? What does the word "phagocytes" mean ?(2). What is the function of blood-plaques ? What are some theories as to their origin ? When are they increased in number ?(3). What is a necessary condition for healthy tissues and organs ? Can the stomach secrete good gastric juice when ulcerated by the use of alcohol ? Can the liver and heart act properly when diseased by the use of alcohol ?(4). What is the function of the blood as regards the effete matter of the system ? Where does the blood take it for elimination ?(5).

SECTION III.

How are the red blood-cells affected in the body by the free use of alcohol ? Name some other things which produce the same effect.(1). What produces a diminution in the size of the red blood-cells ?(2). What is the behavior of the red cells out of the body when treated with alcohol ? Do they touch by their flat surfaces or at their edges ? Do they become smaller or larger ? When the alcohol used is very strong, what effect is produced as regards size, shape, and arrangement ? To what is the irregular condition of their circumference probably due ?(3). What effect is produced by the action of a strong alcoholic extract of opium on red blood-cells ? What additional structures may be seen in the field ? Are red cells ever irregular when treated with opium ? To what is this irregularity due ?(4). What effect is produced by the action of chloral on the red blood-cells ?(5). What is the action of cocaine on the red blood-cells ? Where does the plant from which cocaine is produced grow ? For what is it used by the inhabitants of those countries ? Is the drug ever used in surgery ? For what purpose ? What conditions are produced by the constant use of it ?(6). How do strong solutions of tobacco affect the shape of the red cells ? What effect is produced by its active principle, nicotia ?(7). What is the action of alcohol on the white blood-cells ?(8). What is the action of sulphate of quinia on the white cells ? What effect have currents of electricity on them ?(9). Is alcohol employed as a local dressing for ulcers and wounds ? In what form was it used by the ancients ? In what form is it mostly used now ?(10). Who first saw red blood-cells, and when ? Who first described human red blood-cells, and when ? When and by whom were the white cells described ?(11). Put upon the blackboard the table showing the constituents of the blood.

CHAPTER III.

CELLS, TISSUES, AND ORGANS.

SECTION I.

1. **Cells.**—Every tissue and organ of the body is composed of cells. A cell may be defined as a minute mass of protoplasm, having, generally, a spherical shape, and in its simplest form being homogeneous and destitute of granules, nucleus, and cell-wall.

2. **Protoplasm** is the name of the substance that first manifests the phenomena of life—motion, sensibility, the power to grow in size and to reproduce its kind. All plants and all animals, from the lowest to the highest, begin their existence as a simple protoplasmic cell, and in the beginning it is impossible to tell whether the cell will be an animal or a plant.

3. The word *protoplasm*, which means "first form," was first used by Dr. Hugo von Mohl, in 1846, in describing the contents of certain vegetable cells. The word *sarcode*, meaning "fleshy," was used by Dujardin, in 1835, in describing the structure of some of the simplest forms of animal life. The *protoplasm* of Von Mohl and the *sarcode* of Dujardin are now regarded as being identical, as was shown by Cohn in 1850 and by Max Schultze in 1860. *Bioplasm, sarcode, protoplasm,* are terms

used to denote the living matter of all plants and of all animals.

4. As stated above, the simplest cell is homogeneous in structure and without a cell-wall. A typical cell, however, has a nucleus or kernel, a *nucleolus*, and a number of granules in its substance, the whole being surrounded by a membrane which is the product of the cell, and which is called the cell-wall. The cell-wall of plant-cells is a substance akin to starch, called *cellulose;* the cell-wall of animal cells contains nitrogen, and is albuminous in its nature.

5. The *nucleus* is first formed by an aggregation of the granules of the body of the cell. Cells always reproduce their kind by the nucleus dividing first, then the protoplasm of the body proper of the cell.

6. A single cell forms the whole body and performs all the functions of the simplest plants and animals. These never attain a higher structure. All animals and all plants begin their existence as a cell, which by division and growth and union of newly-formed cells forms tissues, and these, uniting, form organs, which, when properly held together, constitute organic beings—animals and plants.

7. **Tissues** are formed by the union of cells. The cell first divides into two parts, the nucleus dividing first, each of these into two more, and so on until a mass of cells is formed. These now begin to unite or to fuse with each other, forming a tissue, as muscular tissue, nervous tissue, osseous and glandular tissue. The tissues are then properly arranged and combined to form organs, as muscles, bones, nerves, and glands. The cellular structure of plants generally persists with slight

modifications, while in animals the special cell-structure is generally masked by more perfect tissue-formation.

8. Tissues are formed by the aggregation of cells. If any organ be examined, it will be found to be composed of tissues which in turn are composed of cells. Take as an example the liver of one of the higher animals as man. It is composed of definite portions called lobes, of which there are five. These, in their turn, are composed of lobules, and these of true liver-tissue, which is made up of a network of blood-vessels, fine **biliary ducts**, and liver-cells, the cells being the active parts. This starts with the liver, which is an organ made up of lobes, the lobes of lobules, the lobules of liver-tissue—the important part of which is the liver-cells.

So we may go from the simple to the complex, starting with liver-cells, which are held together to form liver-tissue, this united to form lobules, the lobules forming lobes, and the lobes, five in number, constituting the normal organ, the liver.

So the brain may be described as an organ composed of nervous tissue, fibres, and cells, supported by delicate tissue, *neuroglia*. The brain-cells are the active parts in the generation of nervous force, and the fibres conduct that force to some organ for its manifestation.

9. Under certain conditions ordinary protoplasmic cells may be changed into other structures, thus changing one tissue into another.

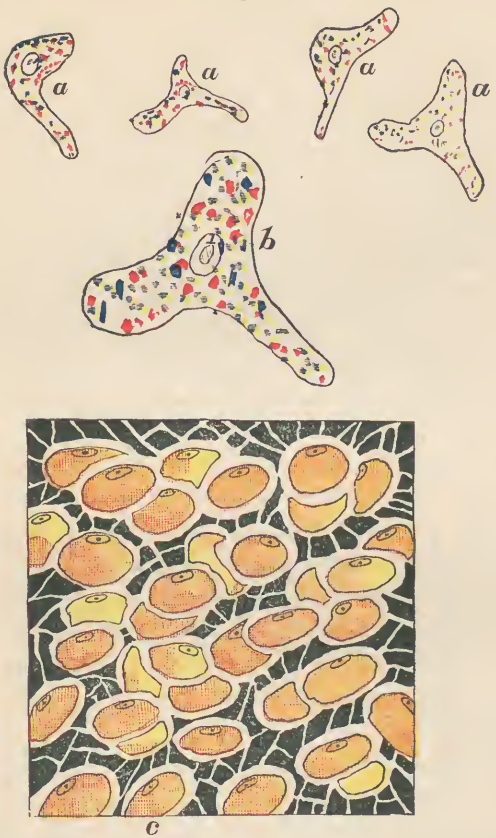
10. Tissues are bound together to form organs, and organs are united to each other to form bodies by **connective tissue**. This name indicates that it is simply a

medium of connection by which the various structures of the body are held together.

11. Ordinary **connective tissue** is composed of very delicate threads of animal matter, which are white and inelastic or yellow and elastic, arranged in a dense network, as in the skin; in a loose network, as in the subcutaneous tissue; or parallel, as in tendons, and having lodged between or upon them protoplasmic cells, or, as they are called here, fibrous connective-tissue cells or corpuscles. The tissue found in the tendons, skin, and subcutaneous tissue is of the white or inelastic variety. In yellow elastic tissue the corpuscles or cells are the same as in the white, but the fibres are yellow in color and will stretch. It is found lining the heart and blood-vessels, around the air-cells of the lungs, and in certain ligaments. The fibres of a connective tissue are held to each other to form bundles by a semi-fluid cement substance of about the consistence of the white of egg. These bundles are held to each other by the same kind of interfibrous semi-fluid cement material.

12. Ordinary **fibrous connective tissue** may be changed into fatty tissue by the protoplasm of the fibrous connective-tissue cell or corpuscle becoming converted into fat. This sometimes happens in disease or under conditions of excessive nutrition, when more food is taken into the body than is needed to repair its waste or to perform its functions. The change begins by the appearance, here and there, of little droplets of fat in the protoplasm of the cell. These gradually increase, and small drops run together to form large ones, until all the protoplasm but a small quantity is removed and its place occupied by fat, which now fills all the interior

Fig. 5.



a, *a*, *a*, *a*, shows connective-tissue cells with pigment in their protoplasm; *b*, same enlarged; *i*, its nucleus; *c*, a group of fat-cells held together by connective-tissue fibres, showing their nuclei near the surface.

of the cell-wall, the nucleus being pushed to the inner surface of the wall and flattened. A fat-cell, then, is composed of an envelope of animal matter, with a

flattened nucleus on its inner surface, surrounding a drop or mass of oil. During starvation or hibernation a fat-cell may be changed, by loss of its oil, into a protoplasmic cell. A number of fat-cells are held together by very delicate fibres of connective tissue to form lobules, and these are held together to form lobes, and lobes of fat are united to form continuous masses. (See Fig. 5.)

13. It sometimes happens that the protoplasm of the cells contains granules of coloring matter, or **pigment**, of varying color—green, brown, black, blue, or yellow—thus changing an ordinary connective-tissue cell or corpuscle into a pigmented connective-tissue cell or a pigment-cell. The protoplasm of the body and processes of the cell may be studded with granules of coloring matter, but the nucleus contains none. (See Fig. 5.)

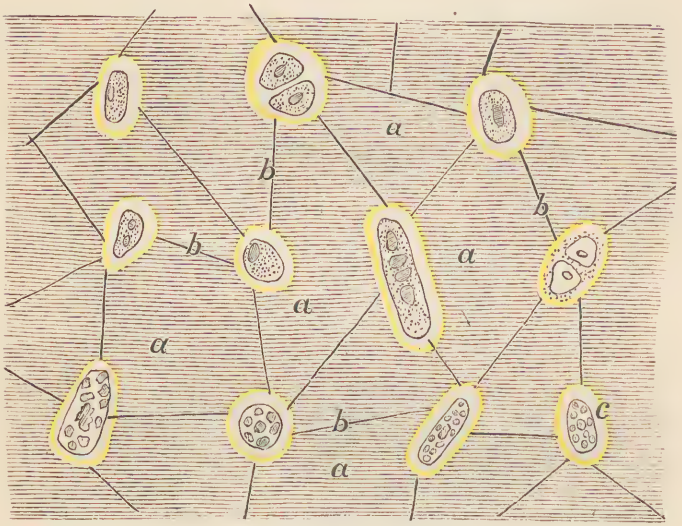
14. Pigment-cells are found in the skin of fishes, amphibians, and reptiles, and give to them their varying color. They also occur in certain tissues of the eye in man and mammals. Darkness causes them to contract, and therefore the tissues in which they are found become lighter in color during such contraction. Sunlight causes them to relax and remain in a passive state, thus causing a tissue containing them to become darker. Certain animals have the power to change color at will, and in these cases the nervous system must regulate the contraction and relaxation of the pigment-corpuscles. The ground-lion (chameleon) is such an animal.

15. **Cartilage** is a connective tissue, the intercellular substance of which is transparent and firm (in *hyaline* cartilage), and the cells are provided with a capsule. Cartilage has no true blood-vessels, but gets its nourishment by a system of channels running through it from

the *perichondrium*—a membrane which covers it and which contains blood-vessels and nerves (Fig. 6).

16. There are three kinds of cartilage: **hyaline**, described above, in which the intercellular substance looks

Fig. 6.



HYALINE CARTILAGE.

a, *a*, *a*, *a*, *a*, the matrix or intercellular substance; *c*, the yellow lines represent the capsule containing the cartilage-cells; *b*, *b*, *b*, *b*, channels of communication between the cartilage-lacunæ.

like ground glass (hence its name), found on the articular surfaces of all bones, on the edges of the sternum, scapulæ, and ilia, in the rings of the trachea and cartilages of the larynx. All the bones of the body except the tegumentary bones of the skull are preformed as hyaline cartilage. The angle of the inferior maxillary bone is

also preformed as hyaline cartilage, the remainder of the bone being preformed in membrane (Fig. 6).

17. In fibrous connective-tissue cartilage the intercellular substance is fibrous tissue, while the cells have a capsule and are called cartilage-cells (*c*, Fig. 6). Here is a tissue which is mixed. It is neither a true cartilage nor a fibrous tissue, hence its dual name. Yellow elastic cartilage is the same as fibrous connective-tissue cartilage, the only difference being that the fibres are yellow instead of white. **Fibro-cartilage** is found between the bodies of the vertebræ and in the neighborhood of joints where true cartilage gradually merges into ligamentous tissue. Yellow elastic cartilage is found in the Eustachian tube, in the ear, and in the two small cartilages of the larynx (Fig. 7).

Fig. 7.



FIBRO-CARTILAGE.

a, *a*, *a*, cartilage; *b*, *b*, matrix of fibrous tissue.

18. **Bone** is a connective tissue, the cement substance which holds the fibres together being replaced by the inorganic salts of lime.

QUESTIONS.

SECTION I.

Of what is every tissue and organ of the body composed? Define a cell(1). What is protoplasm? Name some of its properties. How do all plants and animals begin their existence? Is it possible to tell at first whether a cell will be an animal or a plant?(2). What does the word "protoplasm" mean? When, by whom, and for what purpose was the word first used? When, by whom, and for what purpose was the word "sarcode" used? What does *sarcode* mean? When and by whom was the identity of protoplasm and sarcode shown? What other term is used to express the same thing as sarcode and protoplasm?(3). Has the simplest cell a cell-wall? Name the parts of a typical cell. What forms the cell-wall? What is the difference between the cell-wall of an animal and that of a plant?(4). How is the nucleus first formed? How do cells reproduce? What part of a cell divides first?(5). How are tissues formed? How are organs formed? How are bodies formed?(6). Give some examples of tissues. What is peculiar about the structure of plants? How do they differ in this respect from animals?(7). Of what are organs composed? Of what are tissues composed? Describe the formation of an organ from cells? Begin with the formed organ, and resolve it into its constituent parts.(8). Do protoplasmic cells ever change into other structures?(9). What is connective tissue? What function does it perform in the body?(10). Of what is connective tissue formed? How are the fibres arranged in skin? in mucous membranes? in tendon? How many varieties of connective tissue? Where is the white found? Where is the yellow found?(11). How are fat-cells formed? Name the parts of a fat-cell. How are fat-cells held together? What becomes of the fat-cells during hibernation and starvation?(12). What are pigment-cells? Of what color are they? Does the nucleus ever contain pigment?(13). Where are pigment-cells found? Have they the power to contract? What effect has sunlight on them? What is the effect of darkness? Have any animals the power to change their color by an act of the will?(14). What is cartilage? Has it any blood-vessels? How does it get its nourishment?(15). How many kinds of cartilage are there? What is the character of the intercellular substance of hyaline cartilage? Where is hyaline cartilage found?(16). Describe fibrous connective cartilage. What is peculiar about a cartilage-cell? Where is fibro-cartilage found? Where is yellow elastic cartilage found?(17). What is bone? What kind of material is between its fibres?(18).

CHAPTER IV.

BONES.

SECTION I.

1. *Definition.*—**Bone** is composed of a dense, unyielding groundwork or matrix supporting and containing a number of soft structures.

2. The **groundwork** or **matrix** of bone is the true *osseous* substance. It is formed of a network of fibrous connective tissue, the interfibrous cement substance of which is replaced by the inorganic salts of lime.

3. The **soft structures** of bone are the *periosteum*, marrow, blood-vessels, nerves, and lymphatics.

4. The **periosteum** (around the bone) is the name of a fibrous connective-tissue membrane which surrounds bone: to it muscles, tendons, and ligaments are attached. It contains in its meshes blood-vessels, nerves, and lymphatics, and can be separated into two distinct layers. The external layer is made up of fibrous connective tissue arranged in a dense, compact manner. It is strong and unyielding; hence the agonizing pain caused by a bone felon. The internal layer is also formed of fibrous connective tissue, but the fibres are arranged in a loose manner, forming a soft bed or *nidus* in which are lodged the blood-vessels, nerves, and lymphatics. This layer contains cells (*osteoblasts*), pecu-

liar little bodies that have the power to make new bone, and is sometimes known as the *osteo-genetic* layer. It communicates with the marrow by means of the Haversian spaces and canals. Bone deprived of its periosteum would soon die.

5. **Marrow**, like the layers of the periosteum, is composed of fibrous connective tissue which is very fine and delicate, and which is arranged in a very loose, spongy network supporting arteries, capillaries, veins, and marrow-cells.

6. Marrow is found in the tubular portion of long bones and in the spaces of the cancellous or spongy part of flat and short bones. It communicates with the inner layer (osteo-genetic) of the periosteum, and, in fact, is originally formed from this layer.

7. There are two kinds of marrow—*red* and *yellow*. **Red marrow** is found in all young bones, in the ends of long bones, and in the Haversian spaces of short and flat bones.

8. **Yellow marrow** is found in old bones and in the tubular part of long bones. It is the same in structure as red marrow, the marrow-cells of which have been changed into fat. Red marrow is active in bone-formation. It is also said to have the power to form red blood-cells. Yellow marrow is inactive so far as bone-making is concerned.

SECTION II.

VARIETIES OF BONE.

1. According to the arrangement of the osseous tissue, there are two kinds of bone—*compact* and *cancellous*

or *spongy*. **Compact bone** is found where strength and protection are needed, as in the shafts of long bones and on the surfaces of short and flat bones.

2. **Cancellous** or **spongy bone** is found in the extremities of long bones and in the bodies of short and flat bones. It affords increased surface for the formation of joints, for muscular and ligamentous attachment, gives lightness, and diminishes shock.

3. **Color.**—Healthy bone is of a pinkish-white color.

SECTION III.

CLASSIFICATION OF BONES.

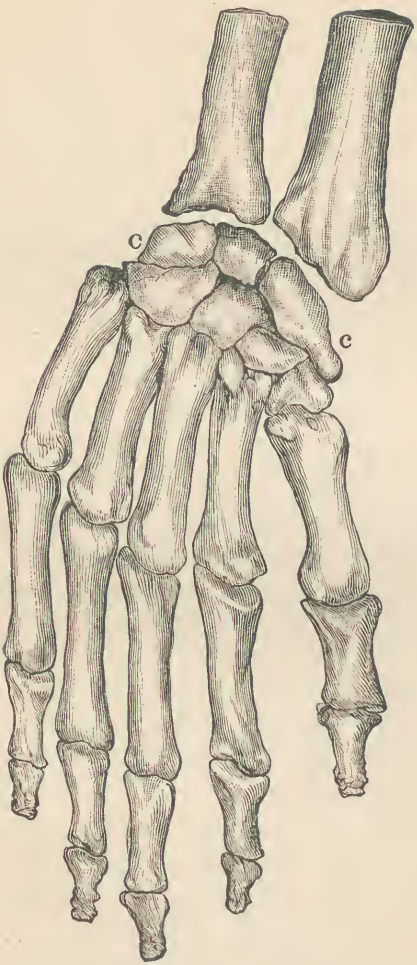
1. For convenience of description, bones are classified into *long*, *short*, *flat*, and *irregular* bones.

2. **Long bones** are found where great range of motion is required, as in the extremities. They have two extremities (*epiphyses*) and an intermediate part—the shaft (*diaphysis*). The **shaft** is composed of compact bony tissue, is hollow in the centre, and contains marrow. The **extremities** are composed mainly of cancellous bony tissue, generally covered with cartilage, and containing a number of irregular spaces (*Haversian spaces*) filled with marrow.

3. **Examples** of long bones are—the *humerus*, or arm-bone; *radius* and *ulna*, or bones of the fore arm; *femur*, or thigh-bone; *tibia* and *fibula*, or bones of the leg; the *metacarpal* bones, or bones of the palm; and the *phalanges*, or bones of the fingers and toes.

4. **Short bones** are found in those parts of the skeleton having limited motion and great strength. They

Fig. 8.



Bones of the wrist and hand, posterior view, right side. *c*, carpus.

are generally bounded by surfaces and angles, and are

composed of spongy bone-tissue covered over with thin layers of compact bone. They are covered with periosteum, and where they enter into the formation of articulations are coated with cartilage.

5. **Examples** of short bones are—the bones of the *carpus*, or wrist-bone (Fig. 8); the bones of the *tarsus*, or ankle-bones (in part); and the *patella*, or knee-cap or knee-pan.

6. **Flat bones** are found where increased surface is needed for muscular attachment and where delicate parts are to be protected. They are covered with periosteum, and are composed of two layers of compact bone, between which is found cancellous bone. In the flat bones of the cranium the layers of compact bony tissue are called respectively the *inner* and *outer* tables of the skull. The spongy tissue between is called the *diploé* (Fig. 9).

7. **Examples** of flat bones are—the bones of the cranium—occipital, parietal, and frontal—which aid in closing the cranial cavity and assist in protecting the brain; *sternum*, or breast-bone, and ribs, which assist in forming the thorax and protect the heart and lungs; *ossa innominata* (nameless bones), or hip-bones, which, together with the *sacrum* behind, form the pelvic cavity and protect the delicate parts within.

8. **Irregular bones** are found in nearly all parts of the central or axial skeleton. They are composed of spongy bone covered with a layer of compact tissue. They are found where there is limited motion and great strength, and where there is great surface for protection and muscular attachment.

9. **Examples** of irregular bones are—the *vertebræ*, or

Fig. 9.



Parietal bones, separated in the median line; shows method of formation of the sagittal suture.

bones of the spinal column; the innominate, or hip-bones, which are also flat in part, but which are so irregular in shape that they have been named the *ossa innominata*, or bones without a name. Other irregular bones are—the *hyoid*, or tongue-bone; *malar*, or cheek-bone; *superior* and *inferior maxillary* bones, or upper and lower jaw-bones.

SECTION IV.

THE SKELETON.

1. **Skeleton** is the collective name used for all the bones of the body. When it is situated within the body, as it is in man and all the higher vertebrate animals (back-boned animals), it is called an *endoskeleton;* when the hard parts for muscular attachment are developed on the exterior of the body, as in crabs, lobsters, and insects, it is called an *exoskeleton.*

2. The skeleton of man is divided into the central or axial skeleton and the peripheral or appendicular skeleton (Fig. 10).

3. The **axial** or **central skeleton** is composed of the bones of the cranium and face, vertebræ, ribs, and sternum.

4. The **appendicular** or **peripheral skeleton** is composed of the scapula and clavicle, ossa innominata, and the bones of the upper and lower extremities.

5. The number of bones in the central or axial skeleton is 74; the number in the peripheral or appendicular skeleton is 126; the number in the complete skeleton being 200. This number does not include the teeth,

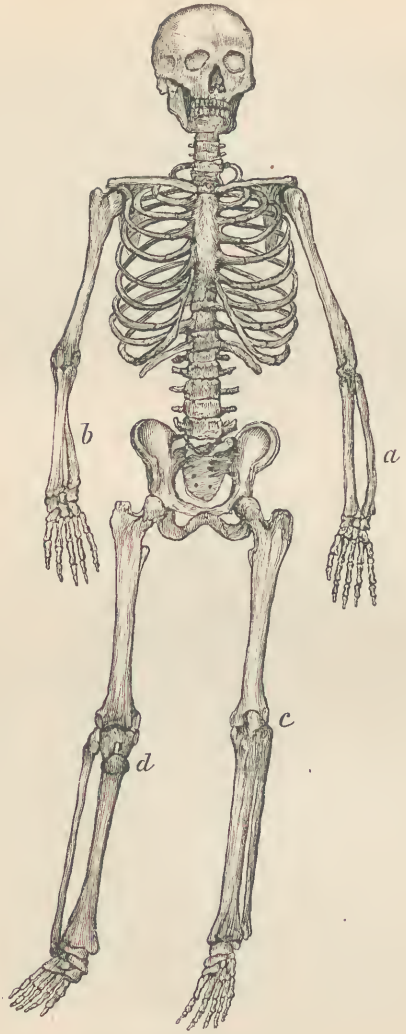


FIG. 10.—THE SKELETON.

a, shows the bones of the fore arm parallel; *b*, shows them crossed; *c*, showing knee-pan or patella in position; *d*, shows it turned down.

which are regarded as not belonging to the true skeleton, or a number of smaller bones—bones of the middle ear and *sesamoid* bones.

SECTION V.

ANATOMY OF BONES.

1. Bones are composed of *laminæ*, or plates, of osseous tissue variously arranged in different parts of the skeleton.

2. **Osseous tissue** is ordinary fibrous connective tissue holding between its fibres inorganic salts of lime. These plates are perforated with numerous fine canals and contain larger oval or round spaces. The little canals are called *canaliculi*, and the spaces are called *lacunæ*, or little lakes (Fig. 11).

3. The **little lakes** or lacunæ contain a cell, and the little canals or canaliculi contain the finger-like prolongations or processes of the cell. The lakes communicate with each other by means of the canaliculi, and the processes of one cell often touch those of neighboring cells. The cells with the processes are the bone-cells (*b*, Fig. 11).

4. In compact bone the **laminæ** or plates of osseous tissue, with their lacunæ, canaliculi, and bone-cells, are arranged in a concentric manner around open canals. This process may be simulated by winding a sheet of paper around a cylindrical stick, and then withdrawing the stick: the sheet of paper will represent the *lamella* or plate of bony tissue arranged in a concentric manner,

and the space previously occupied by the stick will represent the canal. When a number of bony plates are

Fig. 11.

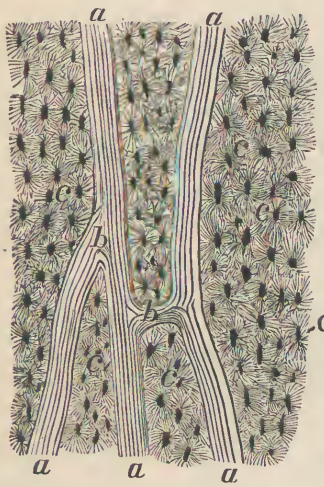


Magnified transverse section of compact bone, showing concentric arrangement of bone lamellæ. *b*, *b*, *b*, *b*, concentric lamellæ, showing lacunæ and canaliculi: the black centre indicates the position of the Haversian canals.

thus wound about a canal, it gives rise to a system of concentric lamellæ; the canal with the surrounding plates forms an Haversian system. The number of laminæ in the Haversian system varies, some canals being surrounded by more bony plates than others.

The canals are called Haversian canals (*a*, Fig. 12) and they communicate with each other by means of branches, so that it is possible to go from one canal to the other (*b*, Fig. 12).

Fig. 12.



Magnified vertical section of compact bone. *a*, *a*, *a*, *a*, *a*, Haversian canals; *b*, *b*, points of communication; *c*, *c*, *c*, *c*, *c*, *c*, *c*, lacunæ and canaliculi.

5. These **Haversian systems**—concentric lamellæ and canals—when stood on end would fall down were they not held together by something. The same kind of bony tissue that forms the concentric lamellæ holds them together. These uniting plates of bone are called *interstitial* or *ground lamellæ*. An idea of their arrangement can be obtained by imagining a number of sticks of chalk, with holes bored through them in their long axes, standing on end; the central opening would represent the Haversian canal, and the chalk would represent the concentric lamellæ. Next imagine a sheet of paper with as many openings in it as there are sticks of chalk, put down in such a way that the sticks of chalk come through the openings. In this way the paper will be found between the sticks of chalk, and represents the arrangement of the interstitial or ground lamellæ. That part of the interstitial lamella which projects beyond the Haversian sys-

tems takes a direction parallel with the long axis of the canals, and forms the circumferential lamella.

6. In cancellous or spongy bone the osseous lamellæ are not arranged in a concentric manner, and do not form Haversian canals. They cross each other at different angles, and form spaces which are sometimes regular and often irregular. These spaces contain marrow and are called Haversian spaces, or *cancelli*.

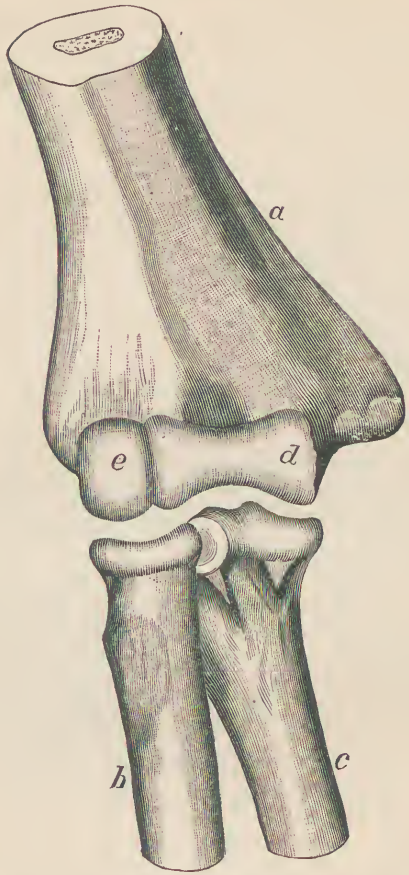
SECTION VI.

PHYSIOLOGY OF THE BONES.

1. Bones subserve a very important function in th economy. They form the framework or groundwork of the body, and afford surface for the attachment of muscles and ligaments. Being acted upon by muscles, they assist in locomotion; hence are called the passive organs of locomotion. They enter into the formation of joints, diminish shock, and afford protection to many delicate parts. (Fig. 13, at *e*, *d*, shows formation of joint.)

2. By being impregnated with the salts of lime the bones become firm and unyielding and afford a support for the body. By containing a certain quantity of animal matter they also possess some elasticity and spring, and thus diminish shock and facilitate locomotion. In the disease *mollitus ossium* (soft bone) the bones lose their inorganic matter (chiefly the phosphate of lime) and become very soft and flexible. They will bend in any direction, and hence cannot support the weight of the body or afford proper points for the attachment of

Fig. 13.



Bones showing the formation of the right elbow-joint. *a*, humerus; *b*, radius; *c*, ulna; *d*, surface for reception of ulna; *e*, surface for reception of head of radius, both covered with cartilage.

muscles. Persons affected with this disease are compelled to lie in the recumbent posture, and are unable

to walk. When dried the bones become transparent, showing that they are composed almost entirely of animal matter.

3. When bones contain an excess of inorganic matter, they become very hard and brittle and are easily broken. The bones of old persons contain an excess of earthy matter, hence are easily broken, a simple fall being often sufficient to cause a fracture. The bones of the young contain an excess of animal matter, and will often bend before they will break. Bones broken in early life readily unite or knit by true bony union. Bones broken in old age often remain ununited or at best form a ligamentous union. Alcohol retards the union of bone by harming the digestive organs, preventing the formation of good blood, and destroying the white blood-cells, which are active in repairing injuries.

4. Muscles are attached to bone through the medium of the periosteum.

5. Were all the bones of the body united into one, locomotion would be impossible. The hands would be useless encumbrances were the bones of the wrist, palm, and fingers firmly soldered to each other. In order that we may execute all the motions necessary to our daily life, the bones of our bodies occur in great numbers and come together in different ways to form joints.

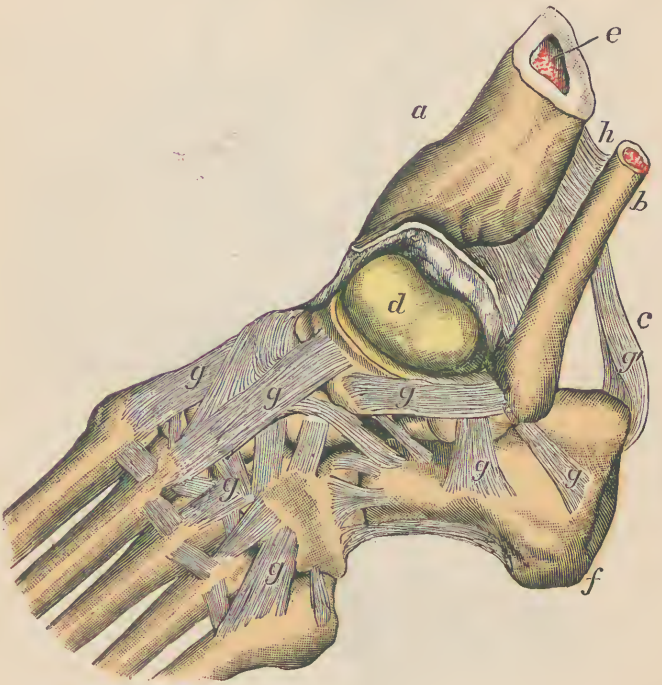
SECTION VII.

JOINTS.

1. The structures that enter into the formation of joints are—bone, cartilage, ligaments, and *synovial mem-*

brane. Where bone enters into the formation of a joint it becomes expanded, and is composed of cancellous tissue with a layer of compact bony tissue surrounding it.

Fig. 14.

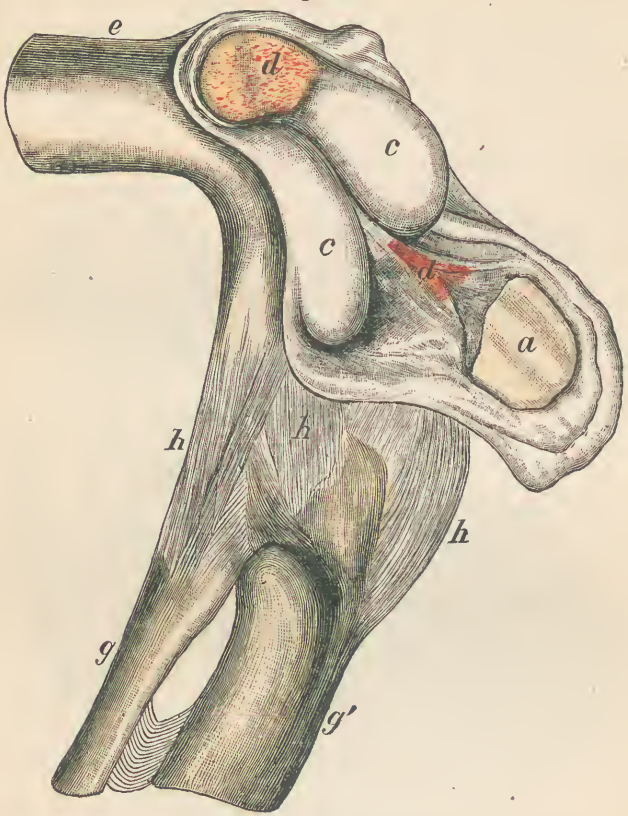


SHOWING LIGAMENTS OF ANKLE AND FOOT.

a, tibia; *b*, fibula; *c* and *g'*, tendo Achilles; *d*, astragalus; *e*, medullary canal of tibia filled with marrow; *f*, os calcis, or heel-bone; *g*, *g*, *g*, *g*, ligaments; *h*, interosseous membrane.

The cancellous tissue diminishes shock, and thus protects the delicate parts of the joint in jumping and striking. On account of the expansion of bone the joints are always larger than the parts above or

Fig. 15.



SHOWING LEFT KNEE-JOINT.

a, patella turned down; *c*, *ć*, condyles of femur covered with cartilage; *d*, *d*, fat; *e*, femur; *g*, fibula; *g'*, tibia; *h*, *h*, *h*, ligaments.

below, and afford a greater surface for the attachment of ligaments and muscles which are to hold the bones forming the joints together (Fig. 14).

2. The **cartilage** that enters into the formation of

joints is of the transparent or *hyaline* variety. It caps the articular surfaces of the bones and acts as a buffer to diminish shock. It is not supplied with nerves, and hence is insensible to pain (*d*, Fig. 14; *c*, *c*, Fig. 15).

3. **Ligaments** are bands or straps of inelastic fibrous connective tissue which run from one bone to the other to hold them in proper position. When the ligaments become stretched or ruptured the joint becomes imperfect, and the bones may be displaced. Joints are also strengthened by muscles and tendons running over them (*g*, *g*, *g*, Fig. 14; *h*, *h*, *h*, Fig. 15).

4. **Synovial membranes** are the oil-sacs of the joints. They are composed of very delicate connective tissue arranged in a dense manner, supporting blood-vessels and lined by from one to four layers of small flattened *endothelial* cells. They secrete a fluid for the lubrication of the joint, so that the motions can take place without friction. The name of this fluid is *synovia*. It resembles in consistence the white of an egg, and is clear or of a pale yellowish color.

SECTION VIII.

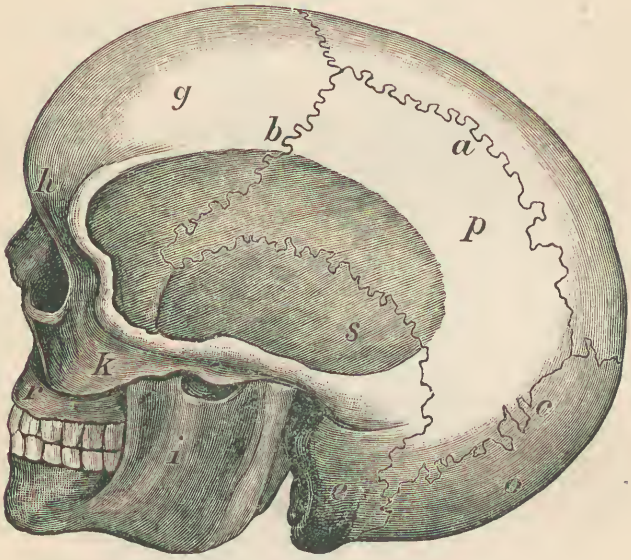
VARIETIES OF JOINTS.

1. Wherever bones come together they form an articulation or joint. In some situations they are freely movable, in others slightly movable, and in still others immovable (Fig. 16).

2. There are several varieties of movable joints. Where motion can take place in but two directions, forward and backward, as in the elbow, a hinge-joint is

found. Where it can take place in all directions, as in the shoulder and hip, a ball-and-socket joint is found. A gliding joint is found where flat or nearly flat sur-

Fig. 16.



SKULL SHOWING SUTURES.

a, sagittal suture; *b*, coronal suture; *c*, lambdoid suture; *c*, mastoid portion; *g*, frontal bone; *h*, superciliary ridges; *i*, inferior maxillary bone; *k*, malar bone; *r*, superior maxillary; *p*, parietal bone; *s*, squamous part of temporal; *o*, occipital bone.

faces of bone move on each other, as between the *sternum*, or breast-bone, and *clavicle*, bones of the *carpus* or wrist, and those of the *scapula*, or shoulder-blade, and *clavicle*, or collar-bone.

3. **Examples** of mixed joints are found in the vertebral column, where the bodies of the *vertebræ* are con-

nected by fibrous connective-tissue cartilage, giving great strength and limited motion, and in the articulations formed by the union of the *ilia*, or hip-bones, with the *sacrum*.

4. **Immovable joints** are found between the bones of the skull in adult life, the teeth, and the maxillary bones (Fig. 16).

5. Where the bones of the *cranium* unite they form sutures or seams, the most important of which are—the *coronal*, or crown, suture, between the frontal and two *parietal* bones; the *sagittal*, formed by the two superior borders of the parietal bones; the *lambdoid* suture, formed by the posterior borders of the two parietal bones; and the *occipital* bone (Fig. 16).

SECTION IX.

FONTANELLES.

1. Where the two parietal bones unite with each other and with the frontal bone there is an absence of bony substance in early life, due to the incomplete ossification of the parietal bones; and in this situation there is no bone separating the brain from external structures. An irregular space exists here through which the pulsation of the brain-vessels may be felt and seen.

2. This appearance of the brain pulsation has been likened to the rising and falling of water in a fountain; hence these spaces have been called little fountains, or *fontanelles* (Fig. 17).

3. In very early life three of these little fountains

may be seen above the base of the skull: the one described above as existing between the frontal bone and the anterior superior angles of the parietal bones, called the *anterior fontanelle;* one between the posterior superior

Fig. 17.



Fœtal skull showing the fontanelles and centres of ossification of the bones.

angles of the parietal bones and the superior angle of the occipital bone, called the *posterior fontanelle;* and one on each side at the posterior inferior angle of the parietal bones (Fig. 17).

4. The two last are closed at birth. The posterior one generally closes within a few months after birth, and the anterior one remains open, often, until the second year, when it is gradually closed by bone from the inner (*osteo-genetic*) layer of the *periosteum.*

SECTION X.

HYGIENE OF THE BONES.

1. **Healthy bone** depends upon healthy marrow, healthy periosteum, healthy blood-vessels, and healthy nerves and lymphatics. These structures, in order to be healthy, must be properly taken care of and must be furnished with healthy blood.

2. The health of all the tissues and organs of the body, including the bones, depends upon a healthy digestive system, furnished with healthy food and drink, and kept in order by carefully obeying the laws of health.

3. **Moderate active exercise**, as walking and horse-back riding, facilitates digestion, the appropriation of new food-material by the body, the removal of worn-out matter, the introduction of oxygen, and the discharge of carbonic acid gas, and is thus conducive to healthy bone-growth.

4. **Very active exercise**, as running, jumping, and dancing, should never be violent or prolonged to the extent of causing marked fatigue. Violent exercise indulged in for a short time causes more profound respiratory efforts, a more complete and thorough change of air in the deeper portions of the lungs, rapid appropriation of oxygen by the tissues, hastened circulation of the blood, and active discharge of effete matter. Thus far it is beneficial, but when carried too far it often causes tissue-waste to an extent beyond repair, producing congestions and inflammations of various organs, ending in diseases which oftentimes cause death.

5. The so-called "growing-pains" of children, which

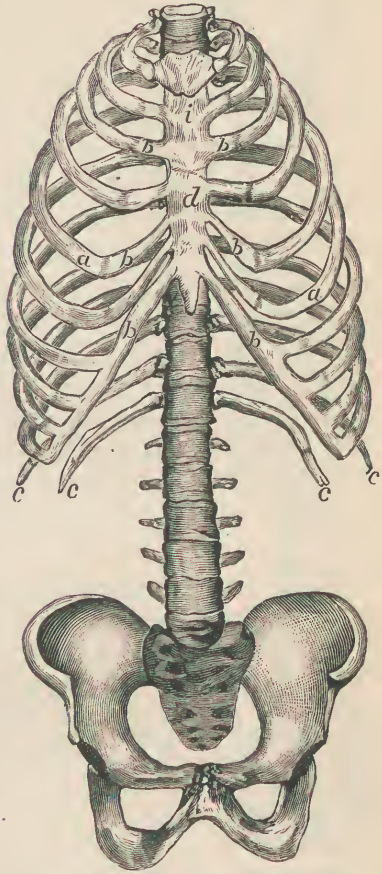
are generally referred to the neighborhood of some joint in the extremities, are often produced by violent exercise. A severe shock to the bone, produced by a jump, causes a rupture of the delicate parts in the immediate vicinity of the joint, generally at the zone of greatest physiological activity. This causes an inflammation, pressure on the delicate nerve-endings, and pain. If the injury be slight, no further trouble is experienced than the "growing-pains," and the damage is soon repaired. If the injury be extensive, however, inflammations of the bone, periosteum, and marrow may be started which will prove a source of pain and trouble for many years.

6. Tight garments, unyielding bands, and bandages should never be worn, no matter how fashionable the dress or imperative the demands of fashion may be. They cause congestion of the vessels by pressure, turn back the blood, and interfere with the nutrition of the tissues. The liver, heart, and lungs have been driven from their normal position, and the stomach so squeezed and deformed by tight lacing as to be unable to perform its function or to hold food enough to nourish an infant. The ribs have been so pushed in and deformed by the repeated application of tight, neat-fitting corsets that the liver after death has been found to bear the marks of their pressure. (See Fig. 18 for normal thorax; also Fig. 46.)

7. By compressing the ribs and muscles of the abdomen to make a neat waist the intestines, liver, kidneys, spleen, pancreas, and stomach are crowded together and pushed up against the diaphragm, displacing the heart and lungs upward and interfering with respiration

and circulation. Many cases of functional heart disease, shortness of breath, and marked forms of indigestion and dyspepsia in fashionable females are occasioned by tight lacing. A noticeably small waist is a deformity as little to be desired as a withered limb or a broken bone.

Fig. 18.



NORMAL THORAX, VERTEBRAL COLUMN, AND PELVIS.

a, a, a, ribs; *b, b, b,* costal cartilages; *c, c, c, c,* floating ribs; *d,* sternum or breast-bone.

8. **Alcohol** predisposes to the fracture of bones, by, in small quantities, stimulating the nervous system, exciting the muscular system, crippling the judgment of the unfortunate victim of its use, and causing him to do many unwise and dangerous things which he would not do in a sober state. In large doses it paralyzes the muscles and maddens the brain, so that they cannot take care of the bones and guard against accidents. Hospital statistics show that were it not for the intemperate use of alcohol in some form,

Fig. 19.



Result of a badly-set fracture, from a cast of the arm of the great African explorer Livingstone.

at least one-third of the beds in the surgical wards could be dispensed with, thus showing that the inebriate not only deprives his wife and children of that physical and moral support which it is his natural and imposed duty to furnish, but he becomes a burden to himself and a care and expense to others in the last days of his helplessness.

9. When bones are fractured or broken, they should be set at the earliest possible moment. Often the broken ends will adjust themselves. Especially is this true where the limb is put in the proper position to insure relaxation of the muscles. A patient with a broken bone, arm or leg, should never be handled until the limb is supported by some kind of splints. When the leg is broken, the patient should not be allowed to attempt to walk, nor should he be carried without first applying some supporting body or bodies to the sides of the limb; and the broken bone should never be examined through the clothing. This should be *cut* and not *pulled* off. By lifting a broken limb without first supporting it, an end of the bone may penetrate the skin and convert a simple fracture into a compound one. An umbrella, a cane, lath, long stick, or pieces of paper folded into thick layers and applied to each

side of the limb, with a handkerchief or twine to hold them fast, is all that is necessary while removing the patient to his home or waiting for the physician. Whenever practicable, *bones should be set before the patient is moved.* Once in proper position they should be let alone. Nature now must do the work of repairing. Unnecessary and unwise handling will be productive of useless pain and delayed union (Fig. 19).

10. **Composition of Bone.**—Bone contains about one-third organic or animal matter and about two-thirds inorganic or earthy matter.

11. **The Chemical Composition of Bone,** according to Berzelius, is as follows:

Organic matter,	Gelatine and blood-vessels	33.30
Inorganic or Earthy matter.	Phosphate of lime	51.04
	Carbonate of lime	11.30
	Fluoride of calcium	2.00
	Phosphate of magnesia	1.16
	Soda and chloride of sodium . . .	1.20
		100.00

To this some chemists add 1 per cent. of fat.

12. By burning bone for some time the animal matter is consumed, leaving the earthy matter, which, though retaining the original shape, is very brittle, and will break to pieces by simply letting it fall upon the floor.

13. By acting upon bone with a dilute mineral acid the inorganic matter is rendered soluble and removed, leaving the animal matter, which still retains the shape, is very flexible, easily cut with a knife, and can be tied into a knot.

SECTION XI.

THE VERTEBRÆ.

1. **The Vertebral Column.**—The number of vertebræ in the back-bone, or spinal column, is twenty-six. Each vertebra or segment of the column is composed of two parts—an anterior part or **body** (*a*, Fig. 20), and a posterior part or **arch** (Fig. 20).

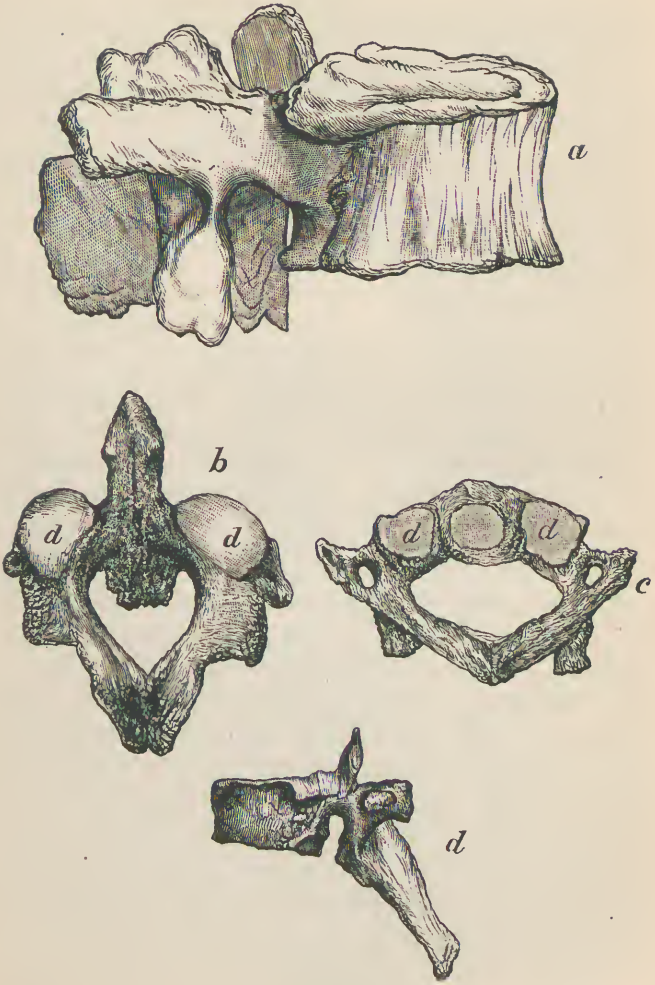
2. The **arch** supports the following processes: two transverse, four articular, and one spinous (Fig. 20).

3. The arch is composed of two *pedicles* and two *laminæ*. The two pedicles spring from the body at the junction of its posterior with its lateral surfaces. The two laminæ are flattened continuations of the pedicles, and, after converging, fuse behind to form the spinous process.

4. The **pedicles** have a general direction backward, and often a little outward. The two laminæ take a direction inward, and generally a little downward, thus enclosing an open space bounded in front by the posterior surface of the body, behind by the converging laminæ and the anterior part of the spinous process, laterally by the inner surfaces of the pedicles and laminæ. This opening, with those in the other vertebræ, forms, when all the segments are articulated, the **spinal canal** and lodges the **spinal cord**.

5. The bodies are the heaviest and most massive parts of the vertebræ (*a*, Fig. 20). They are composed of spongy tissue covered with a thin layer of compact tissue. They are flattened above and below, are rough, and have placed between them disks of fibrous connective tissue

Fig. 20.



VERTEBRÆ.

a, lumbar; *b*, axis; *c*, atlas; *d*, typical dorsal vertebra; *d*, *d*, *d*, *d*, articular surfaces between which the turning movements of the head take place.

which bind them closely together and act as elastic cushions for protection and to prevent shock.

6. The bodies of the vertebræ differ in shape and size in the different regions of the spine. In the *cervical* (or neck) region they are smaller than in any other region, except the *coccygeal.* Their greatest diameter is transversely, or from side to side, their smallest diameter being antero-posteriorly, or from before backward. Hence the to-and-fro (or forward and backward) motion in the neck is greater than the lateral, or from side-to-side, motion. The first cervical vertebra (called the **atlas,** because it supports the globe or head) has no body and no spinous process (Fig. 21). It articulates above with the *condyles,* or knuckles, of the occipital bone, and between these bones the nodding motion of the head takes place (*c, c, c, c, c, c,* Fig. 21). The second cervical vertebra (*b,* Fig. 20) has developed upon its upper surface the body of the first. This process is pointed and in shape not unlike a tooth. It is called the *odontoid* process. This bone articulates above with the inferior surface of the first cervical vertebra (atlas), and between these surfaces the rotatory or turning motions of the head take place (*d, d, d, d,* of *b* and *c,* Fig. 20). The seventh cervical vertebra is peculiar on account of its largely-developed spinous process, and is called the *vertebra prominens.* All of the cervical vertebræ have holes or *foramina* in the bases of their transverse processes for the transmission of vessels. The number of cervical vertebræ is seven.

7. The **Dorsal Vertebræ** are twelve in number, and have the ribs attached to them on each side. Their bodies are larger and heavier than those of the cervical

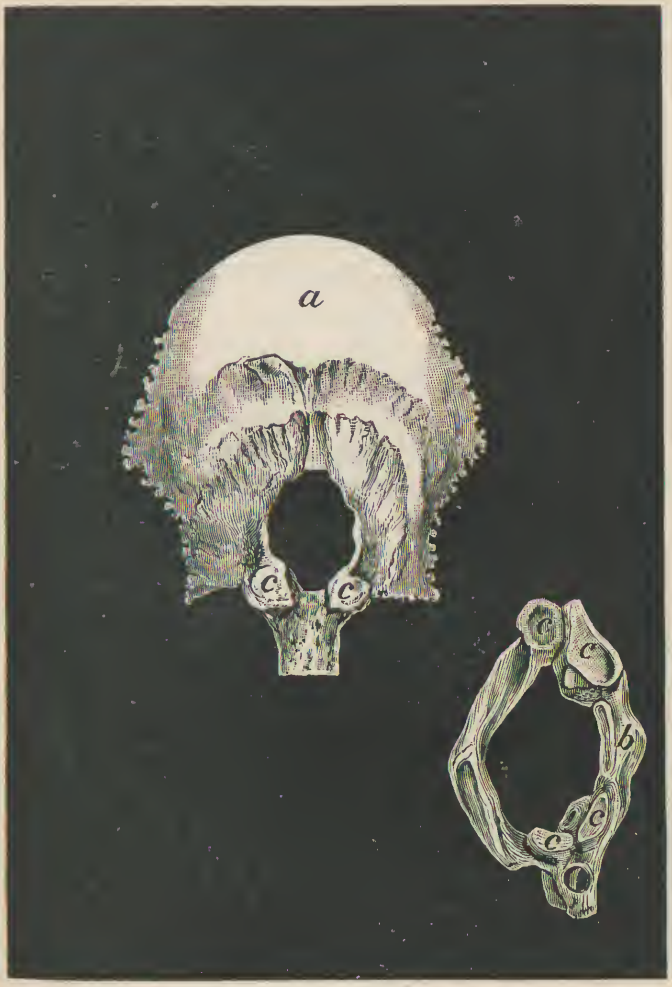


FIG. 21.—OCCIPITAL BONE AND FIRST CERVICAL VERTEBRA.

a, occipital; *b*, atlas; *c*, *c*, *c*, *c*, *c*, *c*, surfaces between which the nodding motion takes place.

region, and have their greatest diameter from before backward and their least diameter from side to side; hence there is greater lateral than forward and backward motion in this region. The bodies are thicker behind than in front, and when piled one upon the other cause this region to be concave in front and convex behind. These vertebræ bear articular surfaces on their bodies and (with few exceptions) on their transverse processes for articulation with the heads and tubercles of the ribs. The **spinal foramen** is round or nearly so, and smaller than in the cervical region, where it is triangular in shape and larger than in any other part of the spine (*d*, Fig. 20).

8. The **Lumbar Vertebræ** are heavy and massive (*a*, Fig. 20), thicker in front than behind; hence in this region there is a convexity in front and a concavity behind. When very marked this produces sway-back. The spinal foramen in this region is triangular in shape, larger than in the dorsal region and smaller than in the cervical.

9. The **Sacrum**, though one bone in adult life, is composed in early age of five bones. These become firmly united or ossified into one piece, forming the sacrum, which is pyramidal in shape, with its apex down and its base up, forming the posterior and upper boundary of the **pelvic cavity**, where it is wedged in between the two innominate bones at the sides, the lumbar vertebræ above, and the coccyx below (*b*, Fig. 22).

10. The **Coccyx** is a small triangular bone composed in early life of four separate pieces, which become ossified into one in the adult. It is pyramidal in shape, with its base up toward the apex of the sacrum and its

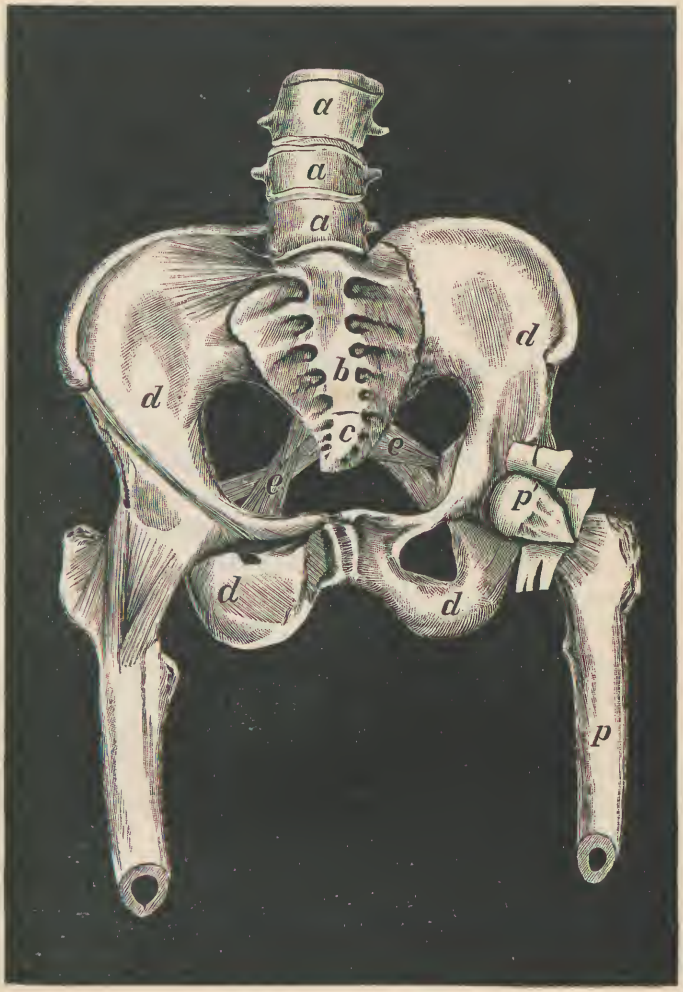


FIG. 22.—PELVIC BONES.

a, a, a, bodies of lumbar vertebræ; *b*, sacrum; *c*, coccyx; *d, d, d, d*, ossa innominata; *p*, femur; *p'*, its head exposed by cutting the ligament away; *e, e*, ligaments.

apex down. All the vertebræ composing it are rudimentary and not well developed. It forms a movable articulation with the apex of the sacrum, which, however, sometimes ossifies, so that the sacrum and coccyx practically become one bone (*c*, Fig. 22).

SECTION XII.

CRANIAL OR HEAD BONES.

1. The **bones of the head** or cranium are eight in number. They are modified vertebræ to contain the anterior enlarged part of the spinal cord, the **brain.** The names of the bones are—*Occipital*, two *Parietal*, *Sphenoid*, *Ethmoid*, *Frontal*, and two *Temporal.*

2. The **Occipital bone** is at the posterior part of the head, and forms the convex projection in this region. It articulates with the posterior borders of the two parietal bones in front, and its inner surface is concave and presents four depressions or concavities. The two upper ones receive the posterior lobes of the *cerebrum*, and the two inferior ones the posterior lobes of the *cerebellum.* In its base is a large oval opening, the *foramen magnum.* This transmits the *medulla oblongata*, which is continuous below with the spinal cord (*a*, Fig. 21).

3. The two **Parietal bones** form the sides and vertex of the head. They articulate with the frontal bone in front and with the occipital behind (Fig. 9).

4. The two **Temporal bones** are situated at the sides and base of the cranium. Each temporal bone is divided into three portions: *squamous*, or scale portion; *mastoid*, or nipple or teat-like portion; and *petrous*, or hard, stone-

like portion. The mastoid portion (*e*, Fig. 16) forms the projection immediately behind the ear. It contains a number of spaces or cavities which communicate with the middle ear. These cavities are called the mastoid cells, and are separated from the brain above by a very thin plate of bone. Diseases of the throat may travel up the Eustachian tube into the middle ear, and then into the mastoid cells.

5. The **Petrous** portion is hard and stone-like, and contains the most important organs of hearing.

6. The **Squamous** portion is thin and translucent, and overlaps the inferior border of the parietal bone. The squamous portion has running outward and forward from its lower part the *zygomatic* process, which articulates with the *malar* or cheek-bone in front, forming the ridge which runs from the cheek backward to the anterior part of the ear.

7. The **Sphenoid** and **Ethmoid** are two very complicated bones wedged in at the base of the skull. They help support the brain, have a number of processes for the attachment of its membranes, and a number of openings for the transmission of nerves and blood-vessels.

8. The **Frontal bone** forms the forehead (*g*, Fig. 16). It articulates behind with the anterior borders of the parietal bones, and its internal surface lodges the anterior lobes of the cerebrum. At the upper part of the orbit, or cavity for the eyes, it presents a distinctly curved arch—the *supraorbital* arch—and running backward from this is the horizontal portion of the bone, articulating with the sphenoid behind and forming the roof of the orbit. Above the supraorbital arches, and

corresponding with the eyebrows, are two ridges of bone called the *superciliary* ridges (*h*, Fig. 16). They indicate the position of the frontal sinuses, which are open spaces developed between the two tables of the frontal bone, containing air and communicating with the nasal cavity. They are not developed in early life.

SECTION XIII.

BONES OF THE FACE.

1. There are fourteen bones in the face: two *Superior Maxillary;* two *Nasal;* two *Inferior Turbinated;* two *Malar;* two *Palate;* two *Lachrymal;* one *Vomer;* and one *Inferior Maxillary.*

2. The two **Superior Maxillary** bones (*i*, Fig. 16) are numbered among the largest bones of the face. Their nasal processes, with the nasal bones, form the sides and bridge of the nose. The anterior part of their bodies forms that portion of the face between the malar or cheek-bones above and the upper teeth below. Their palate processes, with the palate-bones, form the bony roof of the mouth or hard palate and the floor of the nasal cavities. Their inferior borders are thickened and present a number of openings—**alveolar** openings—for the reception of the roots of the upper teeth.

3. The **Inferior Maxillary** bone (*i*, Fig. 16) is the largest bone of the face. It has a body or curved horse-shoe-shaped portion, to which numerous muscles of the mouth and neck are attached, and the upper border of which is also thickened and contains a number of openings to

receive the roots of the lower teeth. Arising from the body on each side at nearly a right angle are the two *rami* or branches. Each of these are *bifurcated* and present surfaces for muscular and ligamentous attachment. The posterior branch of each *ramus* is thickened and rounded, not unlike a knuckle. It is called the *condyle*, and articulates with the *glenoid fossa* on the under surface of the temporal bone. This joint makes it possible to open and close the mouth.

4. There are two **Lachrymal** bones, one on each side. They are situated at the inner and front part of the cavity for the eye. They are the smallest bones of the face, and are very delicate in structure. Their outer surfaces form part of the inner wall of the orbital cavities, their inner surfaces part of the outer wall of the middle openings of the nose. The anterior portion of the outer surface aids the nasal processes of the superior maxillary bone in completing the lachrymal groove, the upper part of which lodges the lachrymal sac, and the lower part helps to form the lachrymal canal, which lodges the nasal duct. This duct carries the tears from the under part of the eye to the *inferior meatus* of the nose, where they are evaporated by the air as it passes in and out during the acts of respiration.

5. The **Malar** bones are two in number, one on each side. They form the prominence of the cheek.

6. The **Vomer** is a long plate articulating above with the sphenoid and below with the superior maxillary and palate bones. It is situated vertically in the posterior part of the *nasal fossæ*, forming the back part of the *septum* of the nose.

7. The two **Inferior Turbinated** bones—one on each

side—are scrolls of spongy bone situated horizontally, from before backward, in the nasal cavity, and attached to its outer wall. These bones separate the middle from the inferior meatus of the nose.

8. The **Palate** bones are two in number, one on each side. They are very irregular bones, and are situated between the sphenoid behind and the superior maxillary bones in front. They help form the roof of the mouth behind and the posterior part of the floor and sides of the nasal cavity. They also have processes entering into the formation of the floors of the orbital cavities.

9. The **Nasal** bones are two in number. They articulate with the frontal bone above, with the nasal processes of the superior maxillary at the outer sides, and with each other in the median line, forming the bridge of the nose.

SECTION XIV.

RIBS AND STERNUM.

1. There are **twelve ribs** on each side (*a*, *a*, Fig. 18). They articulate with the dorsal vertebræ behind, and, with the exception of the lower five, the sternum in front. The seven upper ribs are called the true, or *vertebro-sternal*, ribs. The lower five are called the false ribs; of these the three upper ones are called the *vertebro-chondral*, because they articulate with the vertebræ behind and the costal cartilages in front (*b*, *b*, *b*, Fig. 18). The lower two are called the *vertebral—free* or floating ribs. They have no attachment in front, but are attached to the vertebræ behind (Fig. 18).

2. The **direction of the ribs** is from behind forward and from above downward. They are curved upon themselves, and run from the vertebræ behind to the sternum and costal cartilages in front, enclosing a cavity —*thoracic cavity*—which is bounded above by the root of the neck; behind by the dorsal vertebræ and ribs; laterally by the ribs; in front by the sternum, costal cartilages, and ribs; and below by the muscular diaphragm, which separates it from the abdominal cavity. This cavity contains the heart, lungs, and large blood-vessels.

3. The **Sternum** (*d*, Fig. 18) is a flat bone situated in the anterior part of the chest, forming the anterior boundary of the thoracic cavity. It is broader above than below, and consists of three parts. The first piece is called the *manubrium*, the second the *gladiolus*, and the third the *ensiform* or *xiphoid* appendix. It has been compared in shape to an ancient sword, and the three pieces named the handle, blade, and point. It has articulating with it above on either side the clavicle or collar-bone, on the sides the costal cartilages. Its point is cartilaginous and is free or imbedded in the muscles of the abdomen. A little below the *episternal* notch—which is between the two inner ends of the clavicles in the median line—there can be felt an elevation running transversely which indicates the point of union of the first with the second piece. This ridge is opposite the second rib (*i*, Fig. 18), and is considered, by physicians, an important landmark in examinations of the heart and lungs.

SECTION XV.

THE SHOULDER-GIRDLE AND UPPER EXTREMITIES.

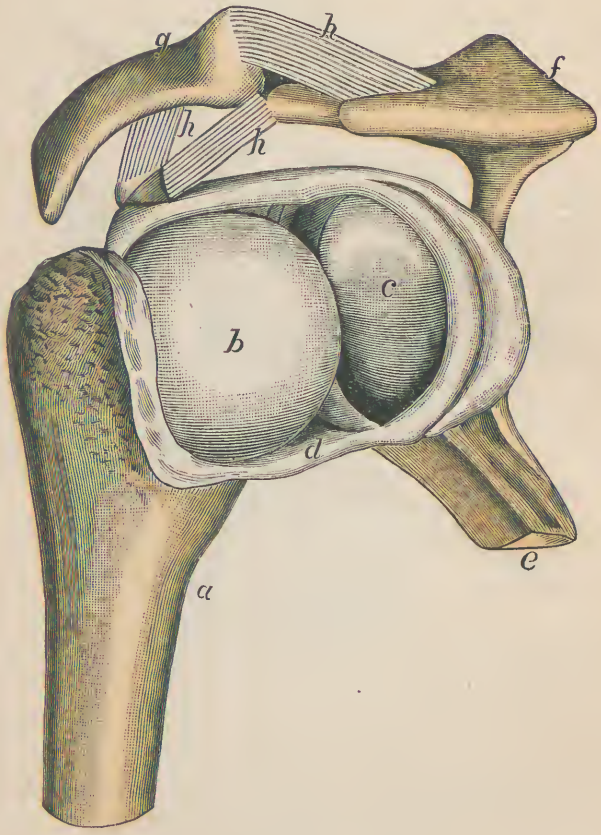
1. There are **two bones** in the shoulder-girdle—the *scapula* and *clavicle*—and they serve to attach the upper extremity to the central skeleton (Fig. 23).

2. The **Scapula**, or shoulder-blade, is a flat triangular bone situated at the upper and posterior part of the thorax. It is imbedded in a mass of muscles which serve to hold it to the body. It articulates with the outer end of the clavicle, and presents, above and in front, an articular surface to receive the head of the humerus, forming the shoulder-joint (*b*, *c*, Fig. 23). A very distinct ridge of bone divides its posterior surface into two parts. This ridge is called the spine of the scapula, and can be felt running toward the median line from the outer and back part of the shoulder. It strengthens the bone and gives increased surface for muscular attachment.

3. The **Clavicle**, or collar-bone (*g*, Fig. 23), is shaped somewhat like the italic letter *f*. It is a strong bone, rather cylindrical in shape, articulates with the *acromion* process of the scapula externally, and with the upper end of the sternum internally. To it muscles of the neck and thorax are attached. This bone is frequently fractured in children, and when this accident occurs the hand of the injured side should be laid on the breast, the arm pushed back, and the shoulder raised. This puts the broken ends of the bone in the best possible position, which should be maintained until the arrival of the physician.

4. The **Humerus** is a long cylindrical bone articulating with the head of the scapula above (*b*, *c*, Fig. 23)

Fig. 23.

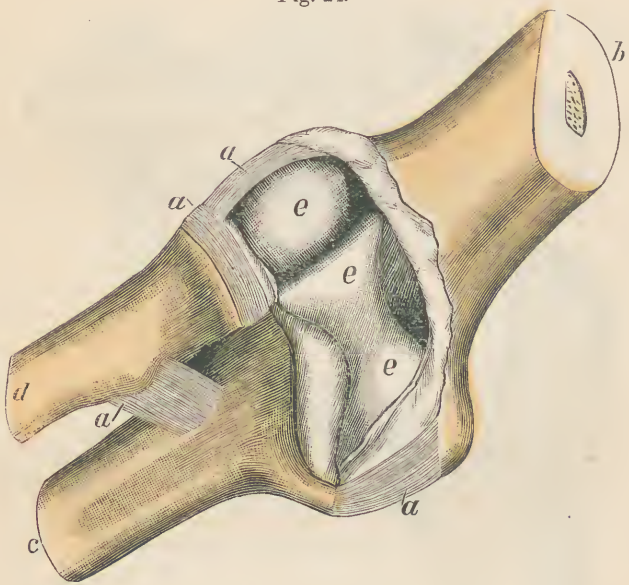


LEFT SHOULDER-JOINT.

a, humerus; *b*, globular head of the same; *c*, glenoid cavity on head of scapula for its reception; *d*, capsular ligament of the joint; *e*, scapula; *f*, its acromion process; *g*, clavicle; *h*, *h*, *h*, ligaments.

and with the radius and ulna below (*e*, *e*, *e*, Fig. 24). This bone forms the arm, and has many muscles attached to it. Where it articulates with the scapula

Fig. 24.



RIGHT ELBOW-JOINT, ANTERIOR VIEW.

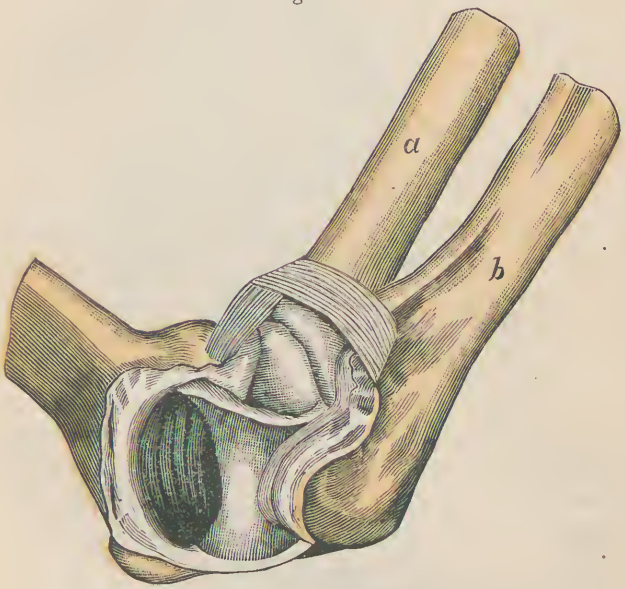
a, *a*, *a*, *a*, ligaments; *b*, humerus sawed off; *c*, ulna: *d*, radius; *e*, *e*, *e*, articular end of the humerus covered with cartilage.

it forms the shoulder-joint, and where it meets the radius and ulna it forms the elbow-joint (Figs. 24, 25).

5. The **Radius** (*a*, Fig. 25) is one of the bones of the forearm, and is placed external to the ulna. It is smaller above than below, and has developed on its upper extremity a rounded portion called the head, which articulates with the outer part of the lower end

of the humerus above and with a depression on the outer surface of the upper end of the ulna at the side. Its lower end is large and rather flattened, and articulates with the *scaphoid* and *semilunar* bones of the first row of the carpus. When the palm of the hand is turned

Fig. 25.



ELBOW-JOINT OF LEFT SIDE, INTERNAL VIEW.

a, radius; *b*, ulna.

down, as in pronation, the lower end of the radius crosses the lower end of the ulna, while its upper end still retains its external position (*b*, Fig. 10). When the back of the hand is down, as in supination, the two bones lie parallel to each other (*a*, Fig. 10).

6. The **Ulna** (*c*, Fig. 24; *b*, Fig. 25) is larger above than below, and enters more largely into the formation of the elbow-joint than the radius. Below it articulates with the side of the radius, but is separated from the bones of the carpus by the interposition of a triangular fibro-cartilage. The sharp point of the elbow is formed by the *olecranon* process of the ulna.

7. The **Carpal** bones, or bones of the wrist (*c*, Fig. 8 and Fig. 26), are eight in number, and are arranged in two rows. Those in the first row are—the *scaphoid*, *semilunar*, *cuneiform*, and *pisiform;* those of the second row are the *trapezium*, *trapezoid*, *os magnum*, and *unciform*. They are short bones, with their articular surfaces covered with cartilage. They give great strength and limited motion. The scaphoid, semilunar, and cuneiform bones, with the lower end of the radius and the lower surface of the interarticular fibro-cartilage at the lower end of the ulna, form the wrist-joint.

8. The **Metacarpal** bones, or bones of the palm, are five in number, one for each finger and the thumb. The *phalanges* are fourteen in number, three for each finger and two for the thumb (1, 1, 1, 1, 1, 2, 2, 2, 2, 2, Fig. 26).

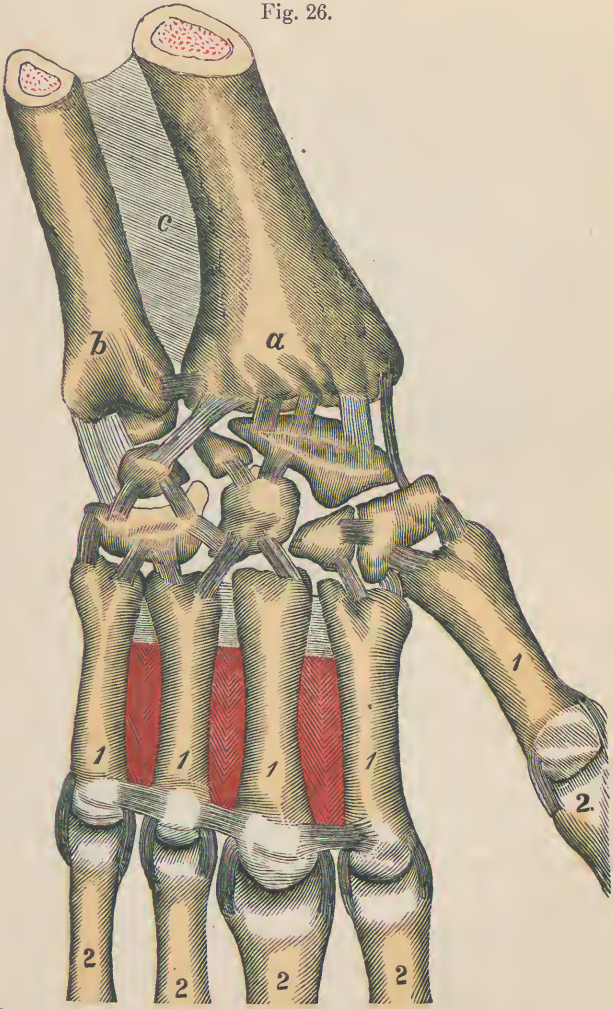
SECTION XVI.

PELVIC GIRDLE.

1. There is one bone in the pelvic girdle on each side, the *os innominatum:* this is composed of three bones in early life, the *ilium*, *ischium*, and *pubes* (*d*, *d*, Fig. 22).

2. The two ossa innominata, with the sacrum and coccyx behind, form the bony wall of the pelvic cavity.

Fig. 26.



SHOWING BONES AND LIGAMENTS OF THE WRIST AND HAND.

The red coloring shows position of interossei muscles, posterior view: *a*, radius; *b*, ulna; *c*, interosseous membrane; 1, 1, 1, 1, 1, metacarpal bones; 2, 2, 2, 2, 2, phalanges.

3. The lower extremity is attached to the central skeleton through the os innominatum.

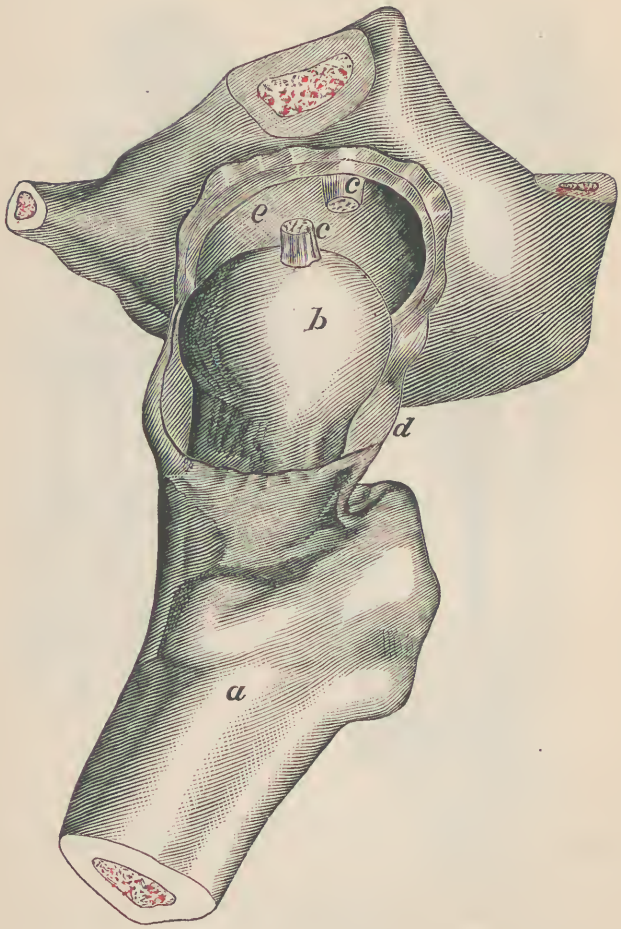
4. The **Femur** (Figs. 27 and 30), or thigh-bone, articulates with the *cotyloid* cavity or *acetabulum* on the outer side of the os innominatum (*p*, Fig. 22, and *c*, *b*, Fig. 27). It is a long bone, and helps form the knee- (*c*, *c*, Fig. 15) and hip-joints, has numerous muscles attached to it, and protects nerves and blood-vessels. In early life this bone is composed of a number of pieces —five—which are not solidly united until the twentieth year of age (Fig. 30). It articulates above with the innominate bone to form the hip-joint, and below with the *tibia* and *patella* to form the knee-joint (*g'*, *a*, Fig. 15). The hip-joint is a ball-and-socket joint. The knee-joint is a hinge-joint.

5. The **Tibia** and **Fibula** (*g*, *h*, Fig. 28) are the bones of the leg, the former occupying the inner side, and the latter the outer side. These bones are parallel to each other. The tibia is much stronger than the fibula, and enters into the formation of the knee-joint above and the ankle-joint below.

6. The fibula (*h*, Fig. 28) is a kind of splint-bone put at the outer side of the leg to strengthen it. It is very flexible, and will bend to a considerable degree before it will break. It articulates above with the upper part of the tibia, below with the tibia and outer surface of the astragalus.

7. The prolonged lower end of the tibia on the inner side forms the inner malleolus, and the prolonged lower end of the fibula on the outer side forms the external malleolus. These prominences may be felt and seen on either side of the ankle (*i*, *i*, Fig. 28).

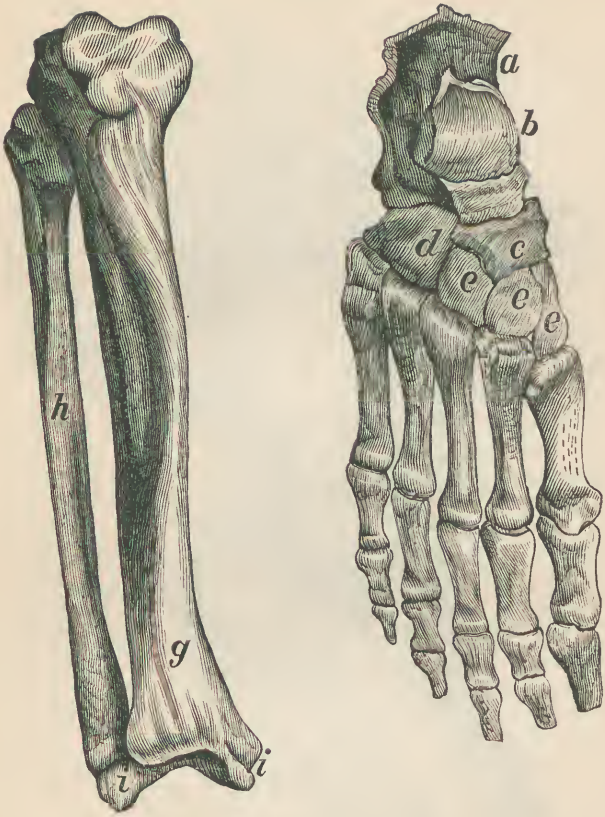
Fig. 27.



HIP-JOINT.

a, femur; *b*, head of the bone; *c*, ligamentum teres; *d*, capsular ligament cut and turned back; *e*, cavity to receive the bone-head.

Fig. 28.



BONES OF THE RIGHT FOOT AND LEG.

a, os calcis; *b*, astragalus; *c*, scaphoid; *d*, cuboid; *e*, *e*, *e*, three cuneiform bones; *g*, tibia; *h*, fibula; *i*, *i*, malleoli.

8. The bones of the **tarsus** are seven in number: the *os calcis* or *calcaneum*, which projects behind and forms the bony prominence of the heel; upon it is the astragalus, articulating above with the lower end of the

tibia and at the sides with the malleoli to form the ankle-joint; in front of this is the scaphoid, then the

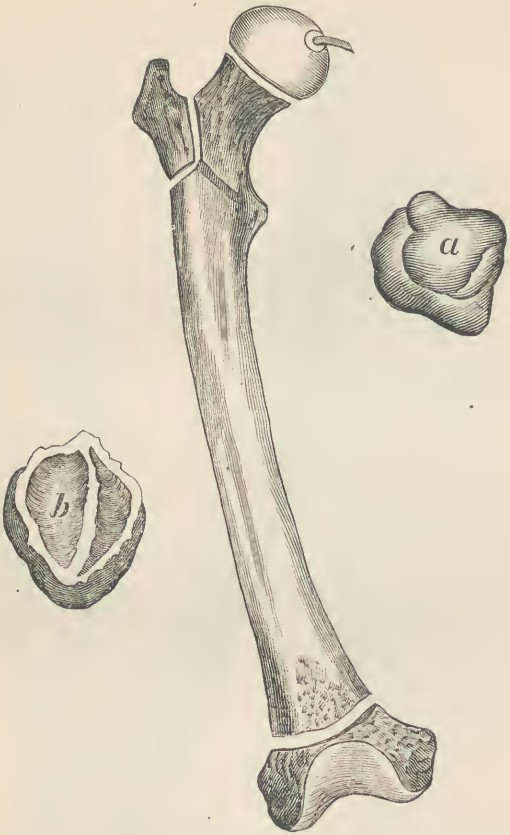
Fig. 29.



FEMUR OR THIGH-BONE OF AN ADULT.

three cuneiform bones—internal, middle, and external—the last being the cuboid (*a*, *b*, *c*, *d*, *e*, *e*, *e*, Fig. 28).

Fig. 30.



FEMUR OF CHILD, SHOWING THE PARTS BEFORE OSSIFICATION IS COMPLETE.

a, patella, front view; *b*, same, posterior view.

9. There are five metatarsal bones, one for each toe; the phalanges are numbered as in the hand.

SECTION XVII.

1. TABLE OF BONES IN THE HUMAN BODY.

Central or Axial Skeleton, 74 bones:			No.
Skull, 22 bones:	Cranium, 8 bones:	Occipital,	1
		Two Parietal,	2
		Two Temporal,	2
		Frontal,	1
		Sphenoid,	1
		Ethmoid,	1— 8
	Face, 14 bones:	Two Superior Maxillary,	2
		Inferior Maxillary,	1
		Two Nasal,	2
		Two Inferior Turbinated,	2
		Two Lachrymal,	2
		Two Malar,	2
		Two Palate,	2
		Vomer,	1—14
Vertebral Column, 26 bones:	Cervical Region,		7
	Dorsal Region,		12
	Lumbar Region,		5
	Sacral Region, 5 bones in early life,		1
	Coccygeal Region, 4 bones in early life.		1—26
Ribs, 24:	True or Vertebro-sternal Ribs, 7 on each side,		14
	False Ribs, 5 on each side:	Vertebro-chondral Ribs, 3 on each side,	6
		Free, Floating, or Vertebral Ribs, 2 on each side,	4—24
Sternum, 1, composed of 3 pieces in early life,			1— 1
Os Hyoides, tongue-bone,			1— 1
			71

2.—APPENDICULAR SKELETON, 126 BONES.

Shoulder Girdle, 2 bones on each side:		No.
	Clavicle,	2
	Scapula,	2— 4

Upper Extremity, 30 bones on each side:			No.
	Arm, 1 bone:	Humerus,	2
	Forearm, 2 bones:	Radius,	2
		Ulna,	2— 6
	Hand, 27 bones:	Carpus or wrist, 8 bones: Scaphoid,	2
		Semilunar,	2
		Cuneiform,	2
		Pisiform,	2
		Trapezium,	2
		Trapezoid,	2
		Os Magnum,	2
		Unciform,	2—16
		Metacarpal, or palm-bones, 5: First,	2
		Second,	2
		Third,	2
		Fourth,	2
		Fifth,	2—10
		Phalanges, or finger-bones, 14: First Row,	10
		Second Row,	10
		Third Row,	8—28

Pelvic Girdle, 1 bone on each side:	Os innominatum, composed in early life of 3 bones — Ilium, Ischium, and Pubes,			2— 2
Lower Extremity, 29 bones on each side:	Thigh, 1 bone:		Femur,	2— 2
	Leg, 2 bones:		Tibia,	2
			Fibula,	2— 4
	Foot, 26 bones:	Tarsus, 7 bones:	Os Calcis or Calcaneum,	2
			Astragalus,	2
			Scaphoid,	2
			Cuboid,	2
			Internal Cuneiform,	2
			Middle Cuneiform,	2
			External Cuneiform,	2—14
		Metatarsus, 5 bones:	First,	2
			Second,	2
			Third,	2
			Fourth,	2
			Fifth,	2—10
		Phalanges, 14:	First Row, 5,	10
			Second Row, 5,	10
			Third Row, 4,	8—28
Patella, or knee-pan, 1 on each side,				2— 2
				126

3. **History.**—With the exception of the bones, the earliest medical men knew very little of the structure of the human body, for they were not permitted to dissect. Definite knowledge of human anatomy began with the foundation of the Greco-Egyptian school of medicine, founded at Alexandria in Egypt about three hundred and twenty years before Christ. The founders of the school licensed the dissection of human bodies, and medical men from all parts of the known world repaired there for instruction. This practice prevailed but a short time, and the dissection of the human body disappeared from history for twelve centuries. The Romans, who gloried in the sight of blood in the arena and on the field of battle, not only burned their dead, but made dissection a crime, and not a single anatomist of any repute obtained his training in Rome. Even the celebrated Galen was compelled to go to Alexandria to see the human skeleton, and, as dissection was no longer

practised there, he sent his students to the battle-fields of Germany to dissect the bodies of the slain. With the death of Galen ended the anatomic period in medicine, A. D. 200. He was at one time court-physician at Rome, was an extensive writer, and is said to have been profoundly versed in osteology. He described, individually, nearly all the bones of the human skeleton, and in his works there are few that are not named.

QUESTIONS.

SECTION I.

Of what is bone composed? What does the matrix support?(1). Of what is the matrix formed?(2). What are the soft structures of bone?(3). What is the periosteum? What is attached to it? Into how many layers can it be separated? What is the character of the upper layer? Why is a bone felon so painful? What is the name of the inner layer of the periosteum? Is it as dense as the outer layer? What does this layer contain? What are osteoblasts? How does the inner layer communicate with the marrow? If the periosteum were cut away from bone, would the bone die?(4). What is the structure of marrow?(5). How many kinds of marrow are there?(6). Where is red marrow found?(7). Where is yellow marrow found? How does it differ from red marrow? Which is active in bone-formation?(8).

SECTION II.

How many kinds of bone are there? What are they? Where is compact bone found? Where is spongy bone found?(1). For what purpose is bony surface increased?(2). What color is healthy bone?(3).

SECTION III.

Into how many classes are bones divided for description? Name them(1). Where are long bones found? Name the parts of a long bone. What kind of tissue composes the shaft? What kind of tissue is found in the extremities? What caps the ends of long bones? What are the Haversian spaces? and what do they contain?(2). Give examples of long bones(3). Where are short bones found? Of what are

they composed? At what points are they coated with cartilage?(4.) Give some examples of short bones(5). Where are flat bones found? Of what are they composed? What covers them? What are the compact plates of bone covering the cranial bones called? What is the diploe?(6). Give some examples of flat bones(7). Where are irregular bones found? Of what are they composed?(8). Give some examples of irregular bones (9).

SECTION IV.

What is the skeleton? What is meant by exoskeleton? By endoskeleton? In what animals are exoskeletons found? In what animals are endoskeletons found?(1). Into how many parts is the skeleton of man divided? Name them (2). What bones compose the axial skeleton?(3). What bones compose the appendicular skeleton?(4). How many bones in the central skeleton? How many in the peripheral skeleton? How many in the entire skeleton? Do the teeth belong to the skeleton?(5).

SECTION V.

Of what is bone composed?(1). What is osseous tissue? What are the canaliculi? What are the lacunæ?(2). What do the lacunæ contain? What are in the canaliculi? Do the lacunæ communicate with each other? Do the processes of one cell ever touch those of its neighbor?(3). How are the bony laminæ arranged in compact tissue? Describe the formation of Haversian canals and Haversian systems(4). What holds the Haversian systems together?(5). What are the circumferential lamellæ? How are Haversian spaces formed? Do they exist in cancellous bone?(6).

SECTION VI.

What part of the body do bones form? How are they useful in locomotion?(1). What makes bone hard? What makes it elastic? What is the condition of the bones in the disease mollities ossium? Can persons who have this affection walk? Why not?(2). Will the bones of old persons break easily? Why? Why will very young healthy bone bend? When the bones of the aged are broken will they unite or knit readily? Why not? How does alcohol act to retard bone-union?(3). By what are the muscles attached to bone?(4). Would it be possible to walk were all the bones of the body united into one? In order that locomotion may be possible, how must our bones be arranged? When bones come together, what do they form?(5).

SECTION VII.

What structures enter into the formation of joints? Why are the joints larger than parts of bone above or below them? What holds the bones forming a joint together?(1). What kind of cartilage enters into the formation of joints? How does it act to diminish shock? Has cartilage sensibility? Why not?(2). What are ligaments? When the ligaments become ruptured, what may happen to the joints? What other structures strengthen joints?(3). What are synovial membranes? Of what are they composed? What kind of cells line the synovial sacs? What do they secrete? What is the name of this fluid? What does it resemble in looks and in consistence?(4).

SECTION VIII.

How are joints or articulations formed? As regards motion, how many kinds of joints are there?(1). What is a hinge-joint? In how many ways can motion take place in hinge-joints? Give an example of a hinge-joint. How is a ball-and-socket joint formed? What kind of motion will be permitted by a ball-and-socket joint? Give an example or examples of a ball-and-socket joint. How is a gliding joint formed? Name some bones between which or by which gliding joints are formed (2). What are mixed joints? What advantage do mixed joints give? Give examples of mixed joints. What holds the different segments of the back-bone together?(3). What are immovable joints? How are immovable joints formed? Are the bones of the cranium firmly united in early life? Give examples of immovable joints (4). What do the bones of the cranium form at their points of union? Name the most important sutures or seams of the head. Between what bones is the coronal suture found? Between what bones is the sagittal suture found? Between what bones is the lambdoid suture found?(5).

SECTION IX.

What are fontanelles? How are they formed? What can be seen and felt at the situation of the fontanelle?(1). What has given rise to the name "fontanelle"? What does the word mean?(2). How many fontanelles may be seen above the base of the skull in early life? Where is the anterior fontanelle? Where is the posterior fontanelle? Name the location of a third one(3). Which fontanelles are closed at birth? When does the posterior one close? At what time does the anterior fontanelle generally close? What is the source of the bone that closes the fontanelles?(4).

SECTION X.

Upon the health of what structures does the health of bone depend? How may these structures be kept in a healthy condition?(1). Upon what does the health of all the tissues and organs of the body depend?(2). What benefit is derived from moderate exercise? How does it affect bone-growth?(3). To what extent should very active exercise be carried? What effects are produced by very active exercise indulged in for a short time only? What effects are produced by very active exercise when carried too far?(4). How are growing-pains in the region of joints often caused? At what part of the joint does the injury generally take place? How is the pain produced? What effect is produced when the injury has been very extensive?(5). Why should tight garments, bands, and bandages not be worn? Is it possible to produce deformity by the repeated application of tight articles of dress?(6). How are respiration and circulation affected by tight lacing? Are functional diseases of the heart ever produced by tight lacing? What sometimes causes dyspepsia?(7). How does alcohol predispose to the fracture of bones? Does the use of alcohol increase the number of surgical cases in the wards of hospitals? Does the use of alcohol damage the user alone, or does it affect others as well?(8). When should bones be set? Will the broken ends ever adjust themselves? Should a broken limb be handled without first supporting it? Should a patient be allowed to attempt to walk with a broken leg? Should a broken bone be examined through the clothing? How should the clothing be removed? Why? What may be used as temporary supports to a broken bone while moving the patient? If practicable, should a bone be set before moving the patient? When once properly set, should a broken bone be handled? Why not?(9). What is the relative amount of animal and earthy matter in bone?(10). What is the chemical composition of bone?(11). How may bone be deprived of its animal matter?(12). How may it be deprived of its earthy or inorganic matter? When can bone be tied into a knot?(13).

SECTION XI.

How many vertebræ in the back-bone? Of how many parts is each vertebra composed? Name them(1). How many processes does the arch support? Name them(2). What pieces compose the arch? From what part of the body do the pedicles spring? What are the laminæ? How is the spinous process formed?(3). What is the direc-

tion of the pedicles? Of the laminæ? What space do they inclose? Bound this opening. What does this opening, with those of the other vertebræ, form? What does the spinal canal contain?(4). What parts of the vertebræ are the heaviest? Of what kind of tissue are they composed? What is their shape? Are their surfaces smooth or rough? What is placed between them? What function does it subserve?(5). Do the bodies of the vertebræ differ in shape and size in the different regions of the spine? Describe the cervical vertebræ. What motion is greatest in the neck? Why? What is peculiar about the first cervical vertebra? What is its name? Between what bones does the nodding motion of the head take place? What is peculiar about the second cervical vertebra? Between what bones does the turning motion of the head take place? What is peculiar about the seventh cervical vertebra? What is peculiar about the transverse processes of all the cervical vertebræ? How many cervical vertebræ are there?(6). How many dorsal vertebræ are there? What is attached to their sides? Describe the bodies of the dorsal vertebræ. What motion is greatest in the dorsal region? Why? Are the bodies of the dorsal vertebræ thicker in front or behind? What condition does this produce? What are found on the sides of these vertebræ? For what purpose? What is the shape of the spinal foramen? What is its size as compared with the other regions of the spine?(7). Describe the lumber vertebræ. How is sway-back produced? What is the shape and relative size of the spinal foramen in the lumbar region?(8). Of how many pieces is the sacrum composed? When do they become united into one piece? What is the shape of this bone? Does its base look up or down? What cavity does it assist in bounding? Between what bones is it situated?(9). Of how many pieces is the coccyx composed? When do they unite? What is its shape? With what bone does it articulate? Does it ever become firmly united to this bone?(10).

SECTION XII.

How many bones in the head? What are these bones? What do they contain? What is the brain? Name these bones(1). Locate and describe the occipital bone. With what bones does it articulate?(2). Locate the parietal bones. With what bones do they articulate?(3). Where are the temporal bones situated? Of how many parts is each composed? Describe the mastoid portion. What are the cells within this portion called?(4). What is the character of the petrous portion? What important structures does it contain?(5). What is the character of the squamous portion? With what part of what bone does it artic-

ulate? What process has the squamous portion? With what bone does it articulate? What prominent ridge does it form?(6). Where are the sphenoid and ethmoid bones situated? Give a gross description of them(7). What does the frontal bone form? Describe as much of this bone as you can. With what do the frontal sinuses communicate? What do they contain? Are they developed in early life?(8).

SECTION XIII.

How many bones in the face? Name them(1). Describe the superior maxillary bones. What part of the nose do they help to form? What part of the face do their anterior surfaces form? What do their palate processes help to form? What is peculiar about their inferior borders? What teeth do they receive?(2). How many parts has the inferior maxillary bone? What teeth does it receive? What joint does it help to form?(3). Where are the lachrymal bones situated? Are they large or small bones? What two cavities do they assist in forming? What groove do they assist in forming? What does this groove contain? What does the nasal duct carry? What becomes of the tears after they enter the nasal cavity?(4). How many malar bones are there? What do they form?(5). Describe the vomer. What does it assist in forming? With what bones does it articulate?(6). How many inferior turbinated bones are there? What kind of bones are they? In what direction do they run? In what cavity are they found? How does it divide this cavity?(7). How many palate-bones are there? Are they regular in shape, or irregular? What cavities do they assist in forming?(8). How many nasal bones are there? With what bones do they articulate? What part of the nose do they form?(9).

SECTION XIV.

How many ribs are there on each side? With what do they articulate in front and behind? What are the seven upper ribs called? The lower five are called what? What is the name of the upper three of the lower five? Which are the free or floating ribs? To what are they attached behind?(1). What is the direction of the ribs? What cavity do they help inclose? Bound the thoracic cavity. What separates it from the abdominal cavity below? What does this cavity contain?(2). What kind of a bone is the sternum? Where is it situated? Of how many pieces is it composed? Name them. To what instrument of war has it been likened? With what bones does it articulate? What causes the ridge on the sternum opposite the second rib?(3).

SECTION XV.

How many bones in the shoulder girdle? Name them. What is their function?(1). Describe the scapula. With what bones does it articulate? What joint does it help to form? (What kind of a joint is the shoulder-joint?) What is the spine of the scapula? What does it do?(2). What is the shape of the clavicle? With what bones does it articulate? What is attached to it? Is this bone frequently fractured? When this accident happens, into what position should the arm be put?(3). What kind of a bone is the humerus? With what bones does it articulate? What part of the upper extremity does the humerus form? What is attached to it? What joints does it help to form? What kind of a joint is the elbow-joint?(4). What is the radius? What is its position with reference to the ulna? What is the head of the radius? With what does it articulate? What is the shape of its lower end? With what bones does it articulate? In what position of the hand does the radius cross the ulna? When do the bones lie parallel?(5). Is the ulna larger above or below? What joint does it help to form above? What separates its lower end from the bones in the first row of the carpus? What forms the prominent point of the elbow?(6). How many carpal bones are there? How many rows do they form? Name the bones in the first row. In the second. What kind of bones are they? What covers their articular surfaces? Does great range of motion take place between them? Do they form strong articulations? Name the bones entering into the formation of the wrist-joint(7). How many metacarpal bones are there? What part of the hand do they form? How many phalanges are there? How many for each finger? How many for the thumb?(8).

SECTION XVI.

How many bones in the pelvic girdle? Of how many pieces is each composed in early life? What are they?(1). What bones form the bony pelvis?(2). How is the lower extremity attached to the central skeleton?(3). Describe the femur(4). Where are the tibia and fibula found? Which is the stronger bone?(5). Describe the fibula. With what bones does it articulate?(6). What bones form the malleoli?(7). How many bones in the tarsus? Name them(8). How many metatarsal bones? How many phalanges in the foot?(9).

SECTION XVII.

How many bones in the central skeleton? Write the bones of this part of the skeleton upon the blackboard(1). How many bones in the appendicular skeleton? Write them upon the blackboard(2). Did the earliest medical men know very much of the structure of the human body? Why not? From what period does definite knowledge of human anatomy date? What advantages were offered to students of anatomy by the Alexandrian school? Did the Romans permit the dissection of human bodies? How did students of anatomy in Rome obtain material for dissection? Who was Galen? Did he possess a knowledge of the skeleton? When did he die?(3).

CHAPTER V.

VASCULAR SYSTEM.

SECTION I.

1. The **vascular system** is composed of the heart, arteries, capillaries, and veins. It is a system of tubes or pipes to distribute blood to the tissues and lungs, and to return it to the heart again.

2. The lowest animals have no such system of tubes to bring them nourishment and to carry off their waste matter. They use the fluid in which they live as blood, and all parts of their bodies take from this fluid all that is necessary for their growth. It is only in the highest animals that there is a perfect circulatory system.

3. The **heart** is the great vascular pump of the body; it is the beginning and the termination of the circulatory apparatus. In the human being it is rather pyramidal in shape, with rounded sides, apex, and base.

4. It is situated in the thoracic cavity, with its base looking up and rather to the right side, its apex looking down and to the left. It is nearer the anterior part of the thoracic cavity than the posterior, and is situated between, and in inspiration nearly covered by, the lungs (Figs. 31, 40, 41).

5. Its base is partly on the right and partly on the

left side, extending about one and a half inches to the right of the median line and three inches to the left. Its upper border is about on a line with the second costal cartilage, its lower border, or the upper border of the third rib. Its apex is between the fifth and sixth ribs, two and a half or three inches to the left of the median line, where it can be felt pulsating.

6. The adult heart weighs from ten to twelve ounces in the male, and from eight to ten ounces in the female. Although absolutely heavier in the male, relatively it is not.

7. The heart has four **cavities**: two auricles above and two ventricles below. The auricle of one side communicates with the ventricle of the same side, but not with the opposite auricle. The ventricles, like the auricles, have no direct communication with each other (Fig. 32).

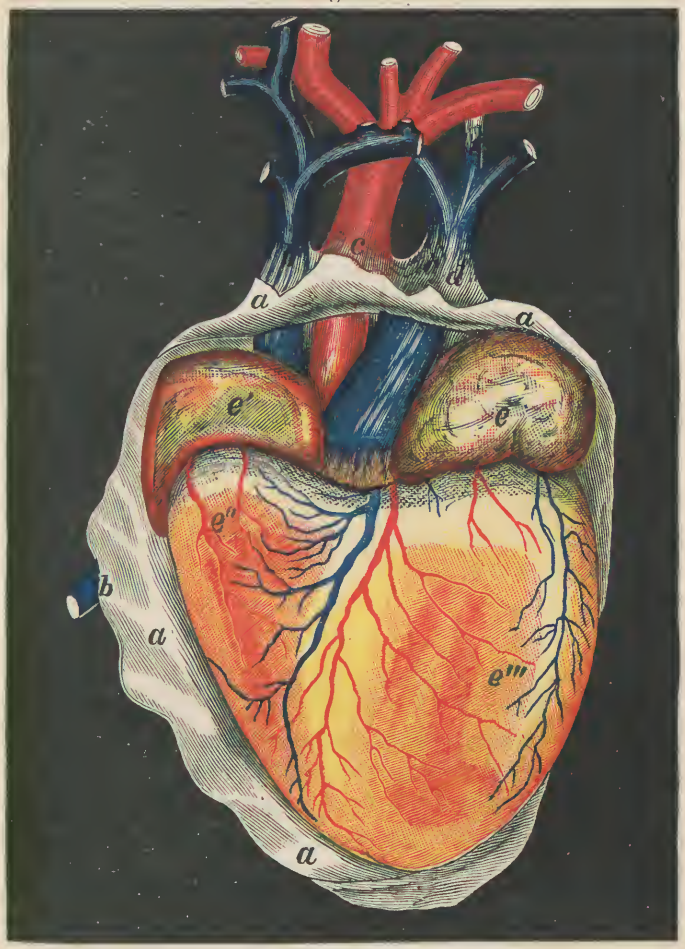
8. The **cavities** of the heart are called: *right* auricle and *right* ventricle, *left* auricle and *left* ventricle (*e*, *e'*, *g*, *g*, Fig. 32).

9. The **right auricle** receives the venous blood from the heart itself, from the body and upper and lower extremities. By contracting, it throws its blood through the auriculo-ventricular opening of the right side into the right ventricle.

10. The **right ventricle**, receiving the blood from the right auricle, contracts and throws it through the pulmonary artery to the lungs, and forces it on to the left auricle (*c*, *c*, Fig. 32).

11. The **left auricle**, receiving the blood from the right ventricle by way of the four pulmonary veins from the lungs, contracts and throws it through the

Fig. 31.



HEART.

a, *a*, *a*, *a*, pericardium cut and turned back; *b*, ascending vena cava; *b'*, descending vena cava; *c*, aorta and branches; *d*, pulmonary artery; 1, ductus arteriosus, a vessel of fœtal life; *e*, left auricle; *e'*, right auricle; *e''*, right ventricle; *e'''*, left ventricle.

auriculo-ventricular opening of the left side into the left ventricle (*e*, *g*, Fig. 32).

12. The **left ventricle**, being filled with blood from the left auricle, contracts and throws it into the aorta, through the arteries, capillaries, and veins, back to the right auricle, the point of starting (*e'''*, *c*, *e'*, Fig. 31).

13. The passage of the blood from the right ventricle through the pulmonary artery, lungs, and pulmonary veins to the left auricle is called the *lesser* or **pulmonary circulation.**

14. The passage of the blood from the left ventricle through the aorta and other branches, capillaries, and veins to the right auricle is called the *greater* or **systemic circulation.**

15. The passage of the blood from the auricles to the ventricles, and from the aorta through the coronary arteries back to the right auricle, constitutes the **cardiac circulation.**

SECTION II.

VALVES OF THE HEART.

1. The openings from the ascending and descending *venæ cavæ*, which bring the venous blood to the right auricle, are not provided with valves, and during the contraction of the right auricle the blood regurgitates into these vessels. Those circular muscular fibres of the auricle which extend to some distance on these vessels constrict their lumen, or diminish their diameter, during the auricular contraction, and act to some extent as valves to diminish the return flow of blood into these vessels. The coronary sinus, which returns the blood

from the substance of the heart, is provided with a valve.

2. The **opening** leading from the right auricle to the right ventricle—auriculo-ventricular opening of the right side—is provided with a valve having three curtains or folds; this is called the *tricuspid valve* (*a'*, Fig. 32), and opens toward the ventricle, closes toward the auricle; thus permitting the blood to flow from the auricle into the ventricle, but not from the ventricle back to the auricle. During the powerful contraction of the ventricle this valve is shut toward the auricle with a clicking sound, and is prevented from being thrown too far by the *chordæ tendineæ*, little tendinous cords which are attached by one end to the inner surface of the ventricle, and by the other to the valves. They act as guys or stay-chains to prevent invagination of the valves.

3. The **tricuspid valve** having closed during the contraction of the right ventricle, the blood is forced past the sigmoid or semilunar valve (*c*, *c*, Fig. 32) of the right side into the pulmonary artery on its way to the lungs. The sigmoid valve of the right side, called also the semilunar and pulmonary valve, is composed of three curtains, which are attached to the inner surface of the pulmonary artery at its junction with the upper part of the right ventricle. During the passage of the blood from the ventricle into the pulmonary artery these valves or curtains are applied against the inner surface of the pulmonary artery. After the ventricle has ceased its action, gravity and the contraction of the pulmonary artery cause part of the column of blood to start back toward the ventricle. This causes

these valves to become closed toward the ventricle, and regurgitation becomes impossible.

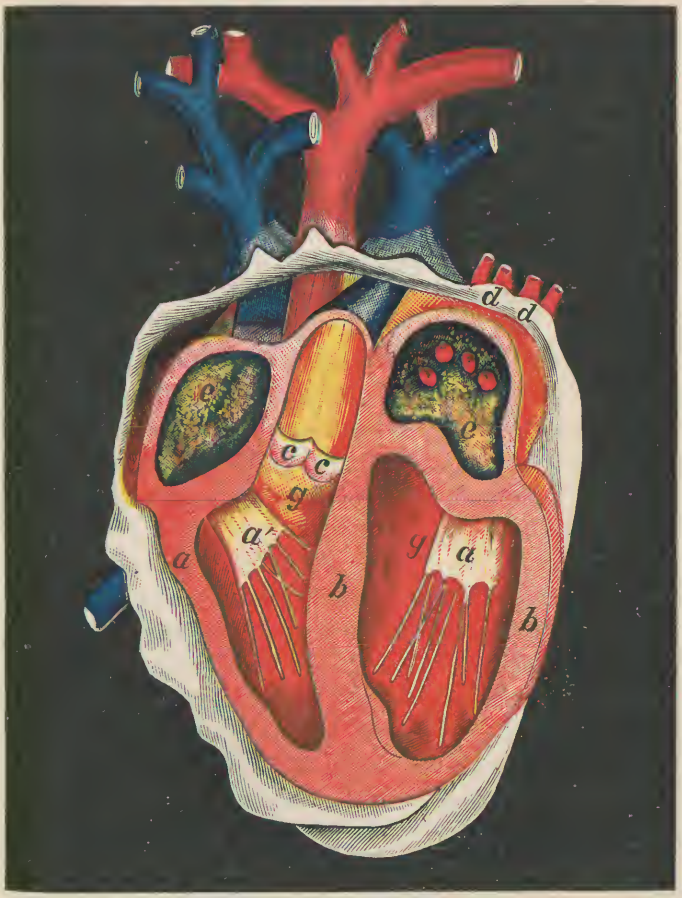
4. The **openings** of the four pulmonary veins leading from the lungs into the left auricle are not provided with valves (*d*, *d*, opening in *e*, Fig. 32). The same arrangement of the circular muscular fibres of the auricle exists here as on the right side of the heart.

5. The **opening** from the left auricle into the left ventricle—auriculo-ventricular opening of the left side—is supplied with a valve having two instead of three curtains, as on the right side; this valve is sometimes called the *bicuspid*, and sometimes, on account of its fancied resemblance to a turban or mitre worn by bishops and cardinals, the *mitral* valve (*b*, Fig. 32). It is so arranged as to permit the blood to flow from the left auricle into the ventricle, and to prevent the flow from the ventricle to the auricle. It presents the same arrangement of tendinous cords as seen on the right side.

6. When the left ventricle contracts, the blood, being prevented by the mitral valve from returning to the auricle, is forced past the semilunar valves of the left side into the aorta, and thence through the arteries, capillaries, and veins to the right auricle. The semilunar or sigmoid valves of the left side are also called **aortic** valves, and bear the same relation to the aorta that the pulmonary valves bear to the pulmonary artery.

7. The student should now endeavor to trace the blood as it goes through the **greater** and **lesser circulations**, holding in mind the condition of the valves during the activity or repose of the various cavities of the heart.

Fig. 32.



HEART WITH ANTERIOR SURFACE CUT AWAY, SHOWING ITS CAVITIES, VALVES, ETC.

b, *b*, walls of left ventricle; *a*, wall of right ventricle; *a'*, tricuspid valve and chordæ tendineæ; *b'*, mitral valve; *c*, *c*, curtains of pulmonic valves; *d*, *d*, four pulmonary veins bringing blood from the lungs; *e*, cavity of left auricle; *e'*, cavity of right auricle; *g*, *g*, corresponding cavities of ventricles.

8. Starting with the right auricle filled with venous blood, this may be done as follows: The right auricle contracts, and throws the blood through the auriculo-ventricular opening of the right side into the right ventricle. During this time there is regurgitation into the ascending and descending venæ cavæ, but not into the coronary vein or sinus. The right ventricle, having been filled with blood from the right auricle, contracts, closes the tricuspid valve toward the auricle, and forces open the pulmonary valves toward the pulmonary artery and lungs, throws the blood through the lungs, and by the pulmonary veins into the left auricle. When the right ventricle has ceased its action, the pulmonary valves become closed and prevent a return of blood into its cavity. The left auricle, being filled with blood from the four pulmonary veins, contracts, and throws its contents into the left ventricle through the auriculo-ventricular opening of the left side. The left ventricle next contracts, closes the mitral valve toward the auricle, and forces open the aortic valves in the aorta to throw its blood through the arteries, capillaries, and veins back to the right auricle by the ascending and descending venæ cavæ. After the action of the left ventricle ceases the aortic valves are closed, like those of the pulmonary artery, to prevent a reflux of blood into the ventricle.

9. The heart is muscular in structure, and is held in position by the great vessels coming from its base. There are two rather distinct layers of muscular substance forming the walls of the heart—an internal circular, which is peculiar to and surrounds each cavity, and an external oblique layer, which is common to and sur-

rounds all cavities. The external layer surrounding the ventricles, at first superficial, runs in an oblique manner from base to apex and from the right to the left side, becomes deep-seated, pierces the deep layer, and appears on the inner surface of the ventricles as little fleshy projections or columns, called *columnæ carneæ*. To these are attached some of the tendinous cords which hold the curtains of the valves in place.

10. The **muscular walls** of the various cavities of the heart differ in thickness according to the amount of work they have to perform.

11. The **thickness** of the walls of the left auricle is about a line and a half; of the right auricle, about one line; of the right ventricle, about two and a half lines; of the left ventricle, about seven lines. The left ventricle has a greater distance to throw the blood than the right ventricle, hence the greater thickness of its walls.

12. The heart is surrounded by a very delicate sac of fibrous connective tissue called the **pericardium**, whose function is to secrete a liquid so that the motions of the heart can take place without friction.

13. The number of **pulsations** in adult life is not far from 70 per minute, though the number may vary within the limits of health. The pulse of Napoleon I. is said to have beat but 40 times per minute. Dunglison records a case even lower than this, where the pulsations were only 36 per minute. The pulse of Sir William Congreve is recorded as never being less than 128 per minute.

14. The heart beats more rapidly in the extremes of life than in the prime of life, being very rapid at birth, when it pulsates 136 times per minute. From this time

it gradually diminishes in frequency until the adult state is reached, after which it begins to increase in the later years of life.

15. The **function** of the heart is to pump blood, and circulation, like respiration, is a part of the great general process of nutrition; and the more perfect the respiratory apparatus, the more perfect must be the circulatory system.

SECTION III.

ARTERIES.

1. **Arteries** is the name given to that part of the vascular system which carries blood from the heart to the capillaries. The name was given to them by Praxagoras before they were known to contain blood and when they were supposed to contain air, the word signifying an air-bearing or air-containing tube or receptacle. It is now known that they carry blood, but they still retain their old name.

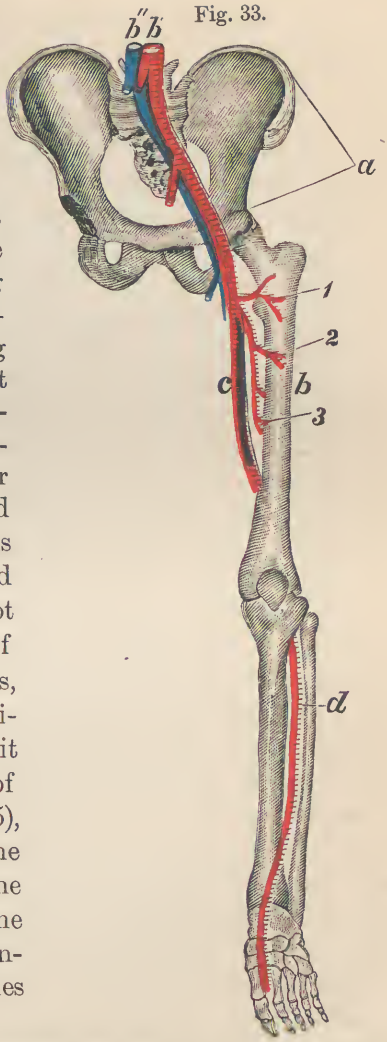
2. The arteries may be said to have their origin from the ventricles of the heart, where they begin as two main trunks—the **pulmonary artery** on the right side, and the **aorta** on the left side. They are supplied with valves only at their beginning (*b'*, *c*, *d*, Fig. 33; *b*, *d*, Fig. 34).

3. They are of a yellowish-white color, very elastic and strong. They divide repeatedly, becoming smaller and smaller as they approach the capillaries: this division is generally dichotomous; that is, each one divides into two branches, and each of these into two

more, and so on until they lose all of their coats but one, when they are known as **capillaries.**

4. The arteries may be described as having four **coats**, or three coats and a lining membrane (*a*, Fig. 35). The **lining membrane** which is continuous with that lining the cavities of the heart is known as the **endothelial coat**, and is composed of a single layer of flattened cells called **endothelial cells.** This layer is sometimes called the endangium, and not only lines the cavities of the heart and arteries, but, following out the divisions of the arteries, it forms the only coat of the capillaries (*c*, Fig. 35), and is prolonged as the lining membrane of the veins back, to become continuous with the lining of the right cavities of the heart.

Fig. 33.



a, pelvic bones; *b*, femur, or thigh-bone; *b′*, artery; *b″*, vein; *c*, femoral artery; *d*, tibial artery; 1, 2, 3, arterial branches.

5. The next coat from within outward is called the **intima**, and is mainly composed of elastic tissue, which is arranged in two distinct sheets or laminæ. This is a very important tunic, and is found best developed in the largest vessels, gradually diminishing as the arteries become smaller. This elastic coat enables the arteries to dilate when they receive the charge of blood from the ventricles, causing the delicate capillaries to receive the blood in a slow and gradual stream. Were all the arteries as inelastic as glass tubes, the capillaries would be subjected to injury with each contraction of the ventricles, and would receive the nutritive fluid rhythmically. The elastic condition of the arteries, however, enables them to accommodate the increased quantity of blood thrown into them with each ventricular contraction, and by their gradual contraction on the column of blood keep up a nearly uniform pressure in the smallest arteries.

6. The **aorta** contains a large quantity of elastic tissue, and after having been distended by the force of the left ventricle it responds in a rebound, during which the aortic valves are closed, and the blood now in the arteries receives an additional impetus which can be felt in arteries of moderate size as the second or **dichrotic pulse.**

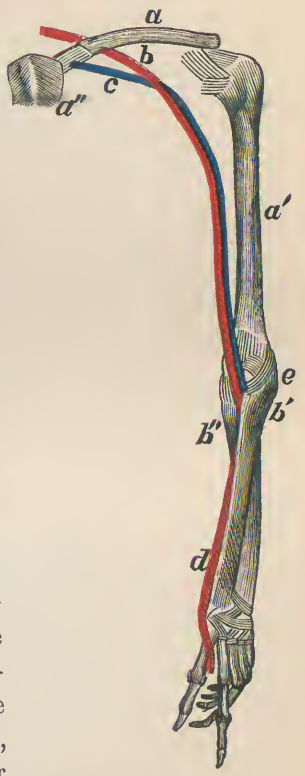
7. The next coat from within outward is the **media**, and is pre-eminently the muscular coat: it is intermingled with elastic tissue, is composed of cellular or involuntary muscular tissue arranged transversely; that is, circularly around the vessel. This coat is not so well developed in the largest arteries, but increases as the intima diminishes. It is present, however, in arteries

of microscopic size. The media is the thickest coat of arteries.

8. The **adventitia** is a poorly-developed coat, and is externally placed. It is composed mostly of fibrous tissue as a very thin layer arranged in the long axis of the vessels. This layer is very thin in the largest arteries, but persists in the smallest. It acts with the media as a support for the vessels that supply the walls of the arteries—viz. the *vasa vasorum*.

9. As the arteries go from the heart they progressively diminish in size, and gradually lose their coats. When the arteries are reduced to very small vessels they retain the internal coat—a very thin representative of the muscular and external coats, the elastic tunic having disappeared. They next lose the *adventitia*, or external layer, and retain the internal layer and a very thin muscular layer: they still have the power of contraction, and can increase or diminish their diameter. Whenever they lose the muscular layer they are called capillaries.

Fig. 34.



a, clavicle; *b*, artery; *c*, vein; *a'*, bone of the arm; *d*, radial artery; *b'*, radius; *b''*, ulna; *a''*, sternum; *e*, elbow-joint.

SECTION IV.

CAPILLARIES.

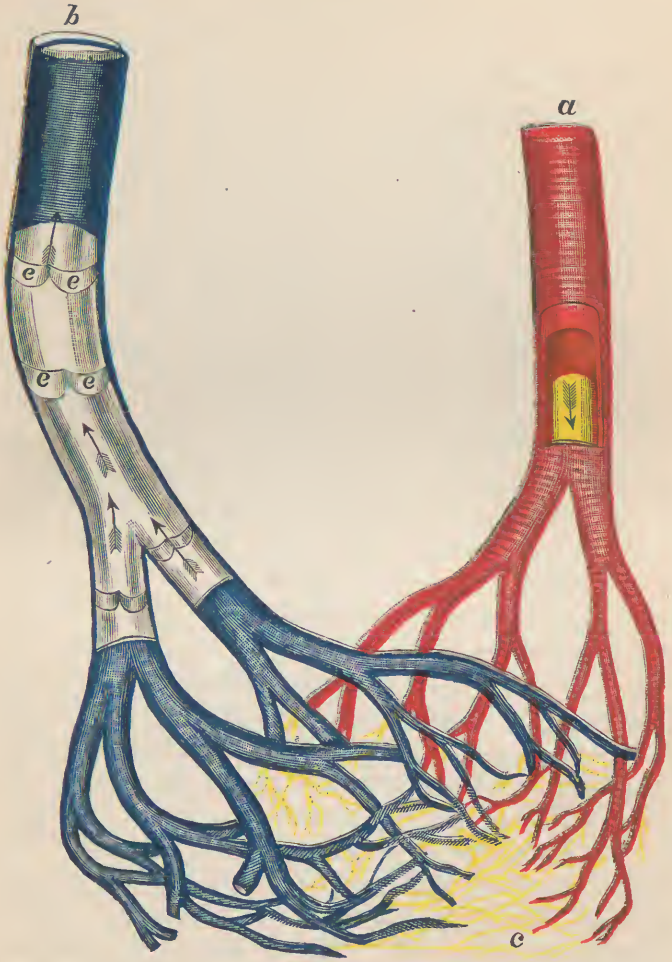
1. The **capillaries** are the small hair-like vessels which connect the arteries with the veins. They are composed of but one layer, which is very thin, and which consists of endothelial cells or of a very delicate membrane lined by or covered with these cells (*c*, Fig. 35).

2. The capillaries, being provided with such thin walls, enable the blood to come very close to the tissues, where it loses its oxygen and constructive matter for tissue-growth, furnishes material for the secretions of the various glands, and receives the carbonic acid gas and effete matter which is produced by tissue-work.

3. The capillaries, unlike the arteries, do not become smaller as they branch, but retain a nearly uniform diameter from their beginning to their termination. They divide and subdivide, unite and reunite, in nearly every possible way to form a dense network or plexus. The flow of blood in them is regulated by the condition of the arteries supplying them, as well as by the condition of the veins which receive their blood. Their capacity is enormous, holding from five to eight hundred times as much as the arteries (Flint); hence they all can never be full at the same time.

4. Their diameter varies in different regions of the body, being as small as from $\frac{1}{5000}$ to $\frac{1}{6000}$ of an inch in the nervous system, and as large as from $\frac{1}{3000}$ to $\frac{1}{2000}$ of an inch in bones. The length of the capillaries is supposed to be about $\frac{1}{50}$ of an inch (Flint).

Fig. 35.



a, artery, showing its coats and branches; *b*, vein, showing the arrangement of its valves; *c*, capillaries. The arrows show the direction of the blood-current. *e*, *e*, *e*, valves.

SECTION V.

VEINS.

1. The **veins** begin by radicles where the capillaries terminate; that is, a capillary grows into a vein by the addition of layers similar to those of the arteries (*b*, Fig. 35; *b''*, Fig. 33; Fig. 36; *a*, *a*, Fig. 37; *c*, Fig. 34).

2. The veins are similar in structure to the arteries, though their coats are thinner and less elastic. In veins the *adventitia* is the thickest coat, and the first to appear when a capillary is changed into a vein.

3. The most striking peculiarity of veins is the presence of *valves* within their lumen to prevent a reflux of blood toward the capillaries.

4. These **valves** are situated at various intervals along the course of the veins, and are composed of the lining endothelium, the whole of the *intima*, and part of the *media*. They are very strong, and have their bases applied to the inner surface of the wall of the veins, their free edges meeting in the centre of the lumen (*e*, *e*, *e*, Fig. 35).

5. The valves do not occur in the very smallest veins. They generally exist in pairs, though three folds are often found in the human subject. In certain portions of the body—viz. the abdomen, lungs, and brain—the veins are not supplied with valves.

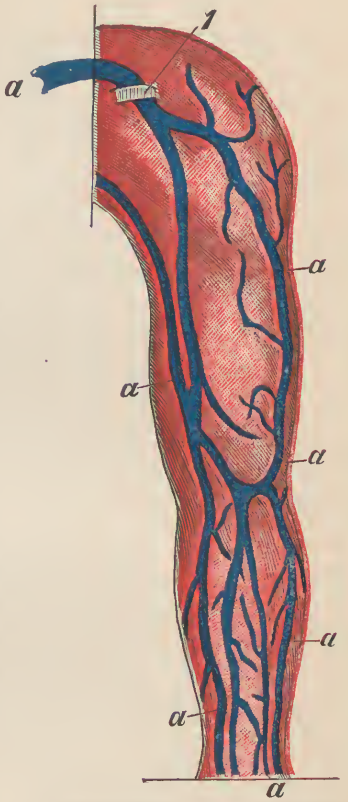
6. The **action** of the valves can be easily demonstrated in any of the superficial veins by preventing the onward flow of blood in the veins toward the heart, when they will swell up and present little elevations at the point of attachment of the valves: by pressing the finger along the course of the swollen vein it can be emptied

toward the heart, but if the pressure be made in the opposite direction, they remain full, and the elevations indicating the point of attachment of the valves become more pronounced.

7. The veins, though thinner than the arteries, are stronger: they are less elastic and have less contractility: they progressively increase in size until they form the two venæ cavæ, which empty the blood directly into the right auricle.

8. The **capacity** of the veins is from two and a half to four times the capacity of the arteries (compare *a*, *a* with *b* of Fig. 37). In the brain the venous capacity is six times as great as the arterial. The flow of blood in the veins is more rapid than in the capillaries, and less rapid than in the arteries.

Fig. 36.



a, *a*, *a*, *a*, superficial veins of upper extremity uniting to form a large vein; 1, a process of fascia running over the vein.

9. Generally speaking, arteries carry arterial or red blood, and veins carry blue or black or venous blood. There are some exceptions, however, where arteries carry venous blood and

where veins carry arterial blood. The pulmonary artery, for example, carries the impure blood from the right ventricle to the lungs for purification, while the pulmonary veins carry the pure oxidized blood to the left auricle on its way to the left ventricle to be sent to the system.

Fig. 37.



a, *a*, *a*, veins; *b*, *b*, *b*, arteries; *c*, arm; *d*, forearm.

10. Any part of the blood completes the circuit of the system in about twenty-three seconds, and the whole mass of blood passes through the heart in about thirty-seven and a half seconds, assuming the heart to beat 72 pulsations per minute, and the left ventricle to discharge all of its blood, which is from five to six ounces, and the quantity of blood in the body to be from one-tenth to one-eighth of the weight of the body (Flint).

11. The **force** exerted by the left ventricle, 51.5 pounds, is sufficient to throw the blood through the arteries, capillaries, and veins, and back to the right side of the heart; but gravity, muscular action, inspiration, and contraction of the veins themselves, facilitate the flow of blood through these vessels.

12. Regular and deep inspirations increase the quantity of venous blood in the thoracic cavity, hastening the circulation in the liver, and diminishing the venous congestion in the head and upper extremities.

SECTION VI.

INFLUENCE OF ALCOHOL ON THE VASCULAR SYSTEM.

1. Small doses of alcohol increase the frequency and force of the heart's action, diminish its period of rest, and increase the pressure in the arteries.

2. This influence is independent of the nervous system, and is seemingly due to the direct action of the alcohol on the substance of the heart itself.

3. Toxic or poisonous doses of alcohol produce paralysis of the heart and arrest its action by direct influence on the heart-muscle. When alcohol is taken into the stomach it gains access to the blood, visits the heart, and if in too great quantity paralyzes this organ and produces death.

4. Authorities differ as to the manner in which alcohol acts upon the heart, some contending that it produces its effect through the nervous system, and others that it acts by direct contact with the heart-substance. In the reduction of temperature which follows the ingestion of large doses of alcohol, the vessels are dilated, and this dilated condition must be due to some effect produced by the alcohol on the vaso-motor nerves which supply the muscular coats of the arteries. The enlarged condition of the capillaries, which have no muscular tunic, is probably due to mechanical distension.

5. Alcohol circulating in the vascular system acts as an irritant to the heart as well as to the vessels, producing inflammations and leading to atheromatous changes or fatty degeneration of the inner coats of the arteries, producing ulcers and diminishing their strength.

6. The blood of habitual users of alcohol, constantly passing through the heart surcharged with this irritant, not only produces irregular and abnormally active contractions, forcing it to increased work without allowing it proper time for rest and appropriation of food, but it destroys its lining membrane by producing inflammation and ulceration like that found in the arteries under similar conditions. When the action of alcohol is prolonged, the muscular substance of the heart itself may be attacked and undergo a fatty degeneration, diminishing its ability to perform work.

7. After death the blood is generally found in the veins, being forced there by the post-mortem contraction of the arterial coats. The dense, strong, and thick structure of arteries causes them to remain open like tubes when cut across, while, with few exceptions, the veins collapse when empty. This is due to the thin walls of the veins as compared with the walls of arteries. The hepatic veins (veins of the liver) remain open when cut across, because their periphery is adherent to the liver substance.

8. **History.**—Hippocrates and the earliest anatomical writers knew nothing of the circulation of the blood, and they confounded the arteries with the veins.

9. Praxagoras was the first observer to notice the difference between the arteries and the veins, and he gave the arteries the name they still bear, supposing them to contain air, and not blood.

10. This observer is supposed to have dissected the human body, and the open condition of the arteries after death probably led him to believe them to contain air.

11. Aristotle, the soldier, physician, and philosopher,

who founded the first Natural History Museum known to the world, lived after Praxagoras, and thought the lungs and heart communicated, and that air came from the lungs into the heart, and thence into the arteries. He knew the heart to be the source of arteries and veins. Historians give conflicting statements concerning his ideas of the arteries, some quoting his work as saying the aorta carries blood, while others contend that he believed this vessel to contain air.

12. Galen, who lived in the second century after Christ, first demonstrated that the arteries carried blood, and wrote a whole book to refute the idea that they carried air. He noticed that at all times, when an artery was wounded, blood gushed out. He afterward included a portion of one of these vessels between two ligatures, and demonstrated by opening it that it contained blood, and not air. He supposed the origin of the veins to be in the liver, showing himself not so far advanced in anatomy as Aristotle, who considered the heart the organ of sanguification.

13. Although the vessels were known to contain blood for many centuries, no approach to the knowledge of the circulation was made until 1553, when Michael Servetus described in a work on theology the passage of blood through the lungs. Cesalpinus first used the term "circulation" after the death of Servetus.

14. Fabricius, the teacher of Harvey, is supposed to be the first who observed the valves in veins: he is said to have described them in 1603, though he says that he saw them in 1574. Valves had been seen in the branches of the portal vein as early as 1545, though they were described by another name.

15. Harvey discovered the circulation and the action of the valves in 1616, and although he clearly demonstrated the direction of the blood-current in the arteries and veins, he did not see the connecting capillaries. Malpighi in 1661 was the first to see the capillary circulation, and completed the discovery of the circulation of the blood.

16. **Hemorrhage.**—Any flow of blood from the arteries, capillaries, or veins is denominated *hemorrhage*, whether there be rupture of the vessels or not.

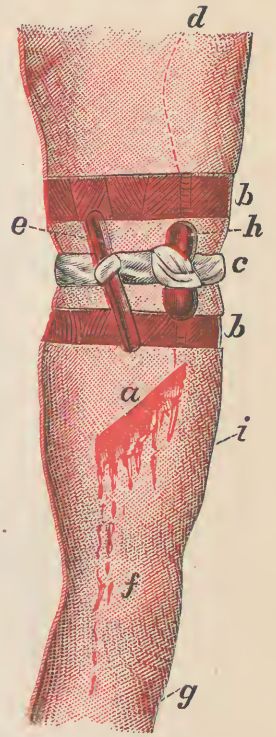
17. The most frequent form of hemorrhage is probably *epistaxis*, or ordinary nose-bleed. It is generally so simple as to be arrested by any of the many means so well known to almost every one. Occasionally, however, it becomes so aggravated as to be dangerous to life, and then more active means must be employed for its arrest. The neck should be freed of all constricting articles of clothing, that the blood in the superficial veins of the neck may not be retarded in its return to the right side of the heart; deep inspirations should be taken to deplete the veins of the head and neck; cold in any form may be applied to the nose, face, neck, and head; the patient should stand erect, and if, for example, the hemorrhage be from the left side of the nose, the left arm should be extended to full length above the head, while the fingers of the right hand compress the nose on the bleeding side. If the bleeding continue, it will be necessary to plug the anterior and posterior nares, and a physician must be called.

18. Accidents frequently occur in which vessels of large size are wounded, and the bleeding is so great that life may be endangered before the necessary surgical aid can be obtained. In emergencies of this kind the

flow of blood may be controlled by firm pressure on the injured vessel above and below the wound if it be an artery, for divided arteries bleed from both ends; below the wound if it be a vein. If pressure enough cannot be brought to bear by the fingers, the tourniquet may be applied (Figs. 38 and 39). It is possible to extemporize an efficient instrument of this kind by tying a knot in a handkerchief and applying it around the limb in such a manner that the knot lies directly over the course of the injured vessel; by tying the two ends of the handkerchief and running between it and the limb a stick, any amount of pressure may be obtained by twisting the handkerchief. In great emergencies a stone or other hard body of suitable size and shape may be included in the handkerchief in place of the knot. (See descriptions of Figs. 38 and 39.)

19. When a vein is wounded, the blood is dark blue or black, and flows in a continuous stream. When an artery is wounded, the blood flows in an interrupted stream, and is bright red in color.

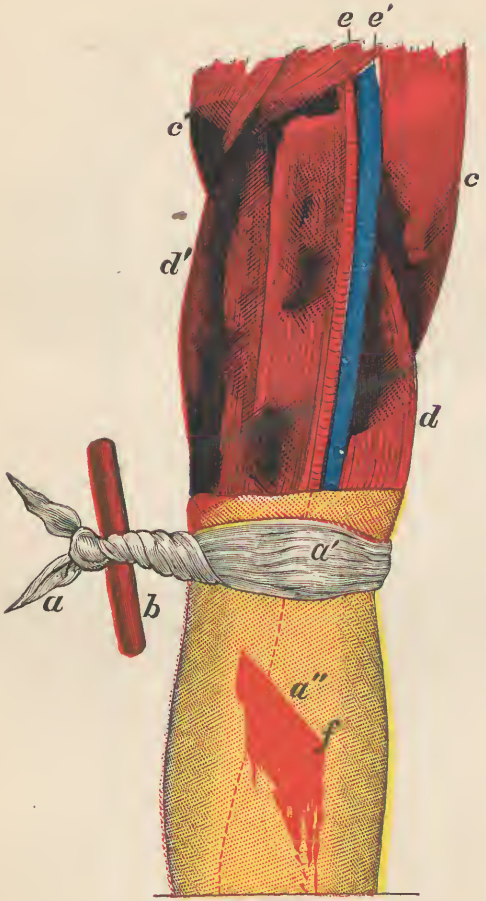
Fig. 38.



METHOD OF APPLYING TOURNIQUET.

a, wound; *b*, *b*, skin cut away, exposing the underlying muscles; *c*, handkerchief applied around the limb; *d*, course of the vessel; *e*, stick used to tighten the grasp of the handkerchief; *h*, stone in the handkerchief to cause pressure on the artery; *f*, knee; *g*, leg; *i*, thigh.

Fig. 39.



APPLICATION OF TOURNIQUET TO ARM.

a, handkerchief; *b*, stick used to tighten it; *a'*, stone in handkerchief over course of wounded vessel; *a''*, integument covering the forearm; *c*, *c'*, *d*, *d'*, muscles of arm; *e*, artery; *e'*, vein; *f*, wound: the red dotted line indicates the course of the artery.

QUESTIONS.

SECTION I.

What is the vascular system? What is its function?(1). Have the lowest animals a special vascular system? Where do they obtain their nutritive matter?(2). What is the heart? What is its shape in man?(3). In what cavity is it situated? In what direction does its base look? Its apex? Is it nearer the anterior or posterior part of the thoracic cavity? What is its relation to the lungs?(4). How far to the right of the median line does its base extend? How far to the left? What marks its upper border? What is the position of its apex? Can it be felt in this situation?(5). What is the weight of the adult male heart? Of the female heart?(6). How many cavities has the heart? Do the auricles communicate with each other? Do the ventricles, in adult life, communicate with each other? Do the auricles communicate with the ventricles?(7). What are the names of the cavities of the heart?(8). From where does the right auricle receive blood? Where does it throw the blood? through what and how?(9). From where does the right ventricle receive its blood? Where and through what does it send it?(10). From where does the left auricle receive its blood? Where, through what opening, and how does it send it?(11). From where does the left ventricle receive its blood? Where, through what, and how does it send it?(12). What is meant by the lesser or pulmonary circulation?(13). What is meant by the greater or systemic circulation?(14). What is meant by the cardiac circulation?(15).

SECTION II.

Are the openings of the ascending and descending venæ cavæ into the right auricle provided with valves? What takes the place of valves here? Is the coronary vein or sinus provided with a valve?(1). Is the opening from the right auricle to the right ventricle provided with a valve? What is the name of this valve? How many curtains has it? In what direction does it open? In what direction does it close? What is its condition during contraction of the ventricle? What are the chordæ tendineæ? What is their function? To what are they attached? (2). Where are the pulmonary valves? How many curtains have they? In what direction do they open? In what direction do they close? What causes them to open? What causes them to close? What

is the function of their valves?(3). Are the openings of the pulmonary veins into the left auricle provided with valves? What takes the place, to some extent, of valves here?(4). Is the opening from the left auricle to the left ventricle provided with a valve? How many curtains has it? Why is it called "mitral"? In what direction does it permit the blood to flow? Is it supplied with chordæ tendineæ?(5). Where are the aortic valves? In what direction do they permit the blood of the left ventricle to flow?(6). Commencing with the blood in the right auricle, describe the lesser and greater circulations, mentioning the direction of the blood-current and condition of the valves during the various stages of activity and repose of the heart(8). What is the structure of the heart? How is it held in position? How many layers of muscular tissue has it? What are they called? What is the relation of each to the cavities of the heart? Where are the columnæ carneæ? What are they? What is attached to them?(9). Why do the walls of the cavities of the heart differ in thickness?(10). What is the pericardium? Of what is it composed? What is its function?(12). What is the thickness of the walls of the right auricle? left auricle? right ventricle? left ventricle? Why are the walls of the left ventricle thicker than those of the right?(11). What is the number of pulsations of the heart per minute in adult life? Does the number vary within the limits of health? What was the pulse of Napoleon I.? Of Sir W. Congreve?(13). Does the heart beat more rapidly in adult life than in the extremes of age?(14). What is the function of the heart? What is circulation? How is it related to respiration?(15).

SECTION III.

What are arteries? What does the word mean?(1). Where and how do the arteries begin? Have they valves?(2). Are the arteries elastic? How do they divide? Do they become smaller as they divide?(3). How many coats have they? Name them. Describe and trace the innermost coat(4). Describe the structure and give the function of the intima(5). Give the function of the elastic tissue in the aorta. What is meant by the dicrotic pulse? How is it produced?(6). Describe the structure of the media. In what size vessels is it best developed? Which is the thickest coat of arteries?(7). What is the position of the adventitia? Is it well developed in arteries? What is the function of the adventitia?(8). Describe the divisions and loss of the coats of arteries until they become capillaries(9).

SECTION IV.

What are the capillaries? What two sets of vessels do they connect? Of how many layers are they composed?(1). In what vessels does the blood come in closest proximity to the tissues? When does it lose its oxygen and gain CO_2? Where does it part with its nutritive matter? Where does it gain its effete matter? How is effete matter produced in the human economy?(2). Do the capillaries become smaller as they divide? What regulates the flow of blood in them? What is their capacity? Are they all ever full at the same time?(3). Are they of uniform diameter? What is their diameter in nervous tissue? in bone? What is their length?

SECTION V.

How do the veins begin? How do they increase in thickness?(1). What is the structure of the veins? What is their thickest coat?(2). What is peculiar about veins? What is the function of the valves?(3). Where are they situated? What is their structure? In what direction do they permit the blood to flow?(4). Are they present in the smallest veins? How do they exist, singly or in pairs? Are there any veins of the body not provided with valves? Name some of them(5). Describe a process by which the action of the valves in a vein can be demonstrated(6). Are the veins as strong as the arteries? Do they increase or diminish in size as they approach the heart? Where do they finally throw their blood? By what vessels?(7). What is the cap of the venous system? What is the condition of the blood-current in the veins?(8). Do arteries ever carry impure blood? Do veins ever carry pure blood? Give examples(9). In what time does any part of the blood complete the circuit of the system? How long does it take all the blood of the body to pass through the heart?(10). What is the force exerted by the left ventricle? Is it sufficient to throw the blood to the right side of the heart? What other factors facilitate circulation in the veins?(11).

SECTION VI.

What is the effect of small doses of alcohol upon the heart?(1). To what is this influence due?(2). What is the effect of large and poisonous doses of alcohol upon the heart?(3). In what way does alcohol act upon the heart? What causes the vessels to dilate? What produces the enlarged condition of the capillaries?(4). What is the action of alcohol

circulating in the blood on the lining membrane of the arteries?(5). What changes does the blood of drunkards produce in their hearts?(6). In what vessels is the blood generally found after death? Why? What is the difference in the walls of arteries and veins? When veins are cut across, will they collapse? Will arteries? Why not? What is peculiar about the veins of the liver—hepatic veins?(7). Did the earliest medical men know anything of the circulation?(8). Who gave the arteries the name they still bear? What did he suppose them to contain?(9). Did Praxagoras dissect the human body? What probably led him to believe the arteries to contain air?(10). What was Aristotle's view of the circulatory apparatus?(11). Who was Galen? When did he live? Did he suppose the arteries to contain air? How did he demonstrate that they contained blood? Where did he suppose the veins to originate?(12). Who first described the passage of blood through the lungs? When? Who first used the term "circulation"?(13). Who first saw the valves in veins? When did Fabricius describe them? When does he claim to have first seen them? Had they been seen prior to this? (14). Who discovered the circulation? When? Who saw first the capillary circulation? When?(15). What is hemorrhage?(16). What is the most frequent form of hemorrhage? How may it be arrested? (17). When vessels are divided and the hemorrhage is alarming, how may it be arrested? If pressure is not effective, what can be done? On what side of the wound must the pressure be brought to bear if an artery is wounded? if a vein is wounded? Describe the application of a tourniquet(18). When a vein is wounded, what is the color of the blood? How does it flow? When an artery is divided, what is the color of the blood? How does it flow?(19).

CHAPTER VI.

RESPIRATION.

SECTION I.

1. **Respiration** is the absorption, appropriation, and destruction of oxygen, and the production and elimination of carbonic acid gas (CO_2) by the tissues.

2. The passage of air into and out of the lungs is not respiration, and the lungs are not the true organs of respiration, only in so far as they form a part of the general structure of the body.

3. Respiration goes hand in hand with circulation, and, like it, is a part of the general process of nutrition; and as animals cannot regenerate their tissues without blood, so it is impossible for tissues to perform their function without oxygen. The more active the animal and the more rapid the circulation, the more perfect must be the oxidation of the blood.

4. When the tissues of the body perform work, they consume nutritive materials from the blood, and use oxygen gas; produce various effete matters and carbonic acid gas. This is absorbed by the blood, and goes by the veins to the right side of the heart, where it is sent to the lungs; here it loses the carbonic acid gas and gains oxygen, red blood being produced from dark-blue blood by the gain of one gas and the loss of the other.

5. This change of venous blood into arterial blood has been called by some "respiration;" this may be true to some extent, so far as the blood itself, as a tissue, is concerned; but evidently the gain of oxygen in the lungs by the blood cannot be respiration, for the vital gas is only now in a condition to visit, with the blood, the tissues; and whenever the tissues consume the oxygen and produce carbonic acid gas, respiration may be said to have taken place.

6. The exact changes which the oxygen undergoes in the tissues before the production of carbonic acid gas is unknown: physiologists and physiological chemists have never been able to trace oxygen in the tissues to the point of its destruction, or to define exactly the changes which take place in its consumption and the production of carbonic acid gas.

7. All animals, from the lowest to the highest, need some oxygen to enable them to perform their nutritive acts. Some need more than others, but in all the tissues demand this gas; and all that is definitely known is, that oxygen is consumed during tissue-work and carbonic acid gas is produced. When animals are deprived of oxygen they die; and death comes more quickly to those in which nutrition is active than to those which are sluggish and slow in their nature. The demand by the tissues for oxygen is more imperative than for food or drink.

8. The great object of the lesser circulation is oxidation of the blood: in the lungs the poisonous matter is exhaled, and the oxygen is taken in mainly by the coloring matter of the red blood-cells. After the blood reaches the left side of the heart, it is sent through the

arteries to the capillaries: in the arteries the blood is uniform in its composition; in the region of the capillaries it loses nutritive material and oxygen, and is changed into non-nutritious blood, which goes into the veins and back to the right side of the heart, to be sent to the lungs for purification. In the veins the blood is not of uniform composition, because as the different tissues vary in their action, so there must be a variety of excrementitious matters produced, and the blood returning, for example, from the brain, will not be of the same composition as that returning from the muscular system. In the lungs these differences are all corrected, and the mixed venous blood is changed into the uniform arterial blood.

SECTION II.

LUNGS.

1. **Lungs** are simply organs of convenience, acting as the media through which the blood loses its carbonic acid gas and gains oxygen. They are membranous or saccular stations developed in the course of the blood-current, by which the blood in its passage through them is exposed to the air which they contain; where the carbonic acid gas and other effete matter is thrown out and where oxygen is taken in (Fig. 40).

2. The simplest animals have no lungs. In them one kind of tissue performs all the work, absorbing oxygen and discharging carbonic acid gas. Higher in the scale of animal life the whole exterior of the body absorbs oxygen. In many sea-worms little tufts or

fringe-like prolongations extend from the sides. They are delicate membranes covering vessels, and absorb the

Fig. 40.

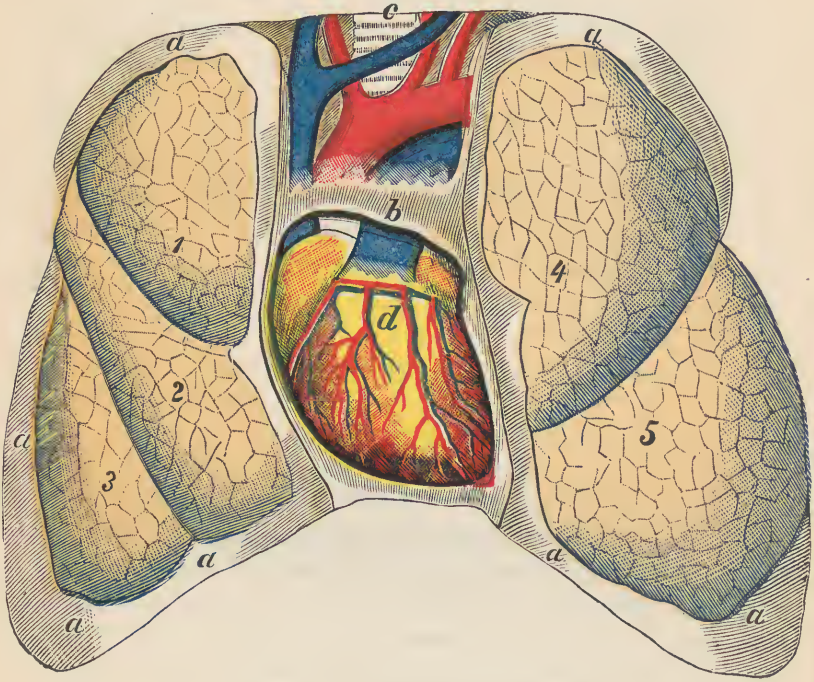


DIAGRAM OF THE HEART AND LUNGS.

1, 2, 3, lobes of right lung; 4, 5, lobes of the left lung; *a*, *a*, *a*, *a*, *a*, *a*, pleura turned back; *b*, pericardium; *c*, trachea; *d*, heart. The red vessel coming from it represents the aorta, the large blue one over the right, the pulmonary artery; the small blue one, the descending vena cava.

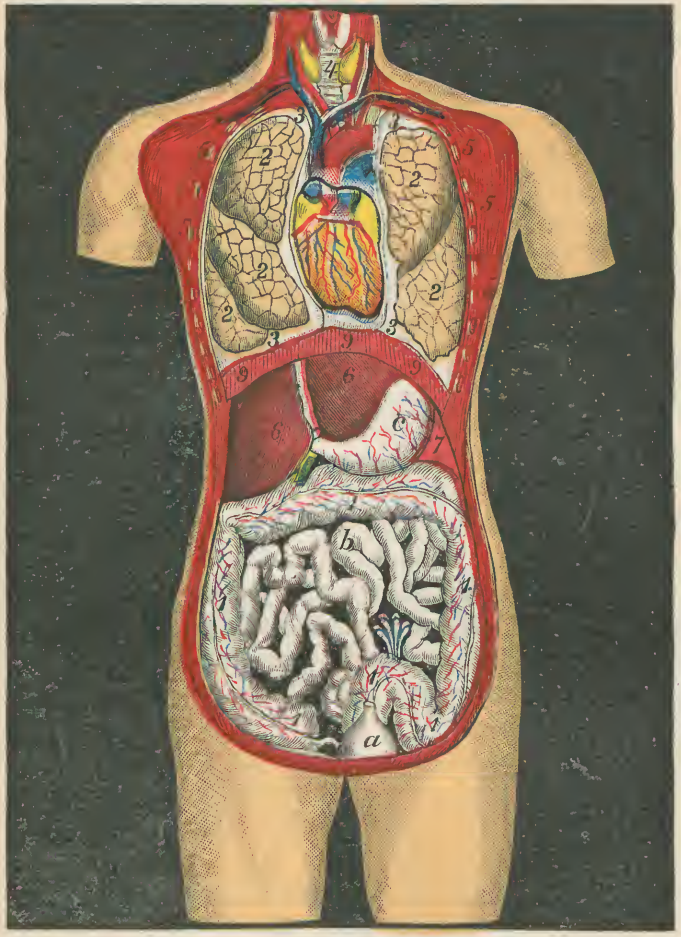
oxygen which is in solution in the water. The gills of fishes are only masses of blood-vessels covered by a delicate membrane, and as the water bathes them the

oxygen which is in solution goes in and the carbonic acid gas comes out. The frog breathes by gills in the tadpole state, but when full grown it has lungs, and also breathes by the skin to some extent. Reptiles have well-developed lungs, which, like all respiratory organs for the introduction of oxygen into the blood-current and the elimination from it of carbonic acid gas, are thin membranous structures containing air and surrounded by delicate capillary blood-vessels. The lungs of birds, mammals, and hence of man, are all constructed on the same type, the necessary conditions being air on one side and liquid on the other side of a permeable membrane. Lungs are simply membranes supporting blood-vessels, and folded or doubled into sacs to occupy less room and at the same time to present a great surface.

3. The smaller the folds or sacs of lungs the greater the surface presented, and the larger the sacs of course the less surface. The lungs of amphibians and reptiles are coarse in structure; that is, the air-sacs are large. The lungs of birds and of man are fine in structure; that is, they are composed of great numbers of small sacs, and hence present a great surface separating the blood from the air.

4. The **ventral** or belly cavity of man is divided into two parts by a muscular horizontal partition; the name of this muscular partition is the *diaphragm.* The division below the diaphragm is called the *abdominal* cavity, and it contains the stomach, small and large intestines, liver, spleen, pancreas, and kidneys. The upper division is called the *thoracic* cavity, and contains the heart, with the great vessels coming from its base, and the lungs (Fig. 41).

Fig. 41.



DESIGNED TO SHOW THE RELATION OF THE ORGANS IN THE THORACIC AND ABDOMINAL CAVITIES.

1, 1, 1, 1, large intestine; *a*, bladder; *c*, stomach; 2, 2, 2, 2, 2, lobes of the lungs; 3, 3, 3, pleura cut away; 5, 5, 5, muscles showing ends of cut-off ribs; 4, trachea; 7, spleen; 6, 6, liver, with the gall bladder; 9, 9, 9, diaphragm; 10, heart.

5. The **thoracic cavity** is bounded behind by the dorsal vertebræ; laterally, by the ribs; in front, by the sternum and cartilages, which attach this bone to the anterior ends of the ribs; below, by the diaphragm, and above, by the root of the neck.

6. It is wider from side to side than from before backward, and is longer posteriorly than anteriorly. It is much larger in all dimensions at its base below than at its apex above.

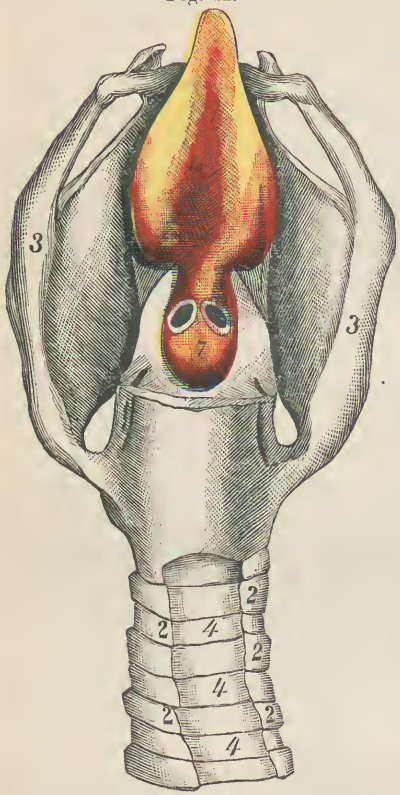
7. The **diaphragm** is dome-shaped, with its convex surface up toward the thoracic cavity, and its concavity down toward the abdominal cavity. It may be likened in shape to a palm-leaf fan, with its handle tacked to the backbone and the leaf pulled forward and fastened to the lower margins of the circumference of the thorax; or to a parasol hoisted from the abdomen, the handle being pushed back against the anterior surface of the vertebræ and the margins made fast to the periphery of the thorax below. Its convexity is more marked during expiration. During inspiration it becomes more nearly flat.

8. Anterior to the opening which leads from the throat into the gullet or *œsophagus* is the opening into the larynx, which is the upper cartilaginous portion of the windpipe or *trachea*, which leads into the lungs (7, Fig. 42).

9. The **larynx** is the name of the cartilaginous box at the beginning of the trachea. It is rigid in its structure, so that it will not collapse during the act of inspiration. In this box, stretched across its upper opening, are the four vocal cords—two *superior*, and two *inferior;* the two inferior ones are alone concerned in phonation,

and are called the true vocal cords. The two superior ones are called the false vocal cords; they run from before backward, are close together in front, and are separated behind.

Fig. 42.



1, epiglottis; 2, 2, 2, 2, 2, rings of the trachea; 4, 4, 4, posterior surface of the trachea, unoccupied by cartilage; 3, 3, hyoid bone; 7, opening into the larynx.

10. The air enters between the vocal cords, and this little slit-like opening is called the *rima glottidis*. Muscles are attached to cartilages of the larynx in such a manner as to enable the cords to approximate each other behind or to diverge, thus opening and making passive the aperture between them.

11. During inspiration the slit is opened, and air rushes into the trachea and its divisions, the bronchi. During expiration they fall nearly together, leaving only a narrow opening.

12. The entrance to the *glottis* is closed during the act of deglutition by a little triangular leaf-like body called the *epiglottis* (1, Fig. 42). During the acts

of breathing the epiglottis stands up and rests against the posterior surface of the tongue. It prevents the entrance of liquids and particles of solid food into the trachea.

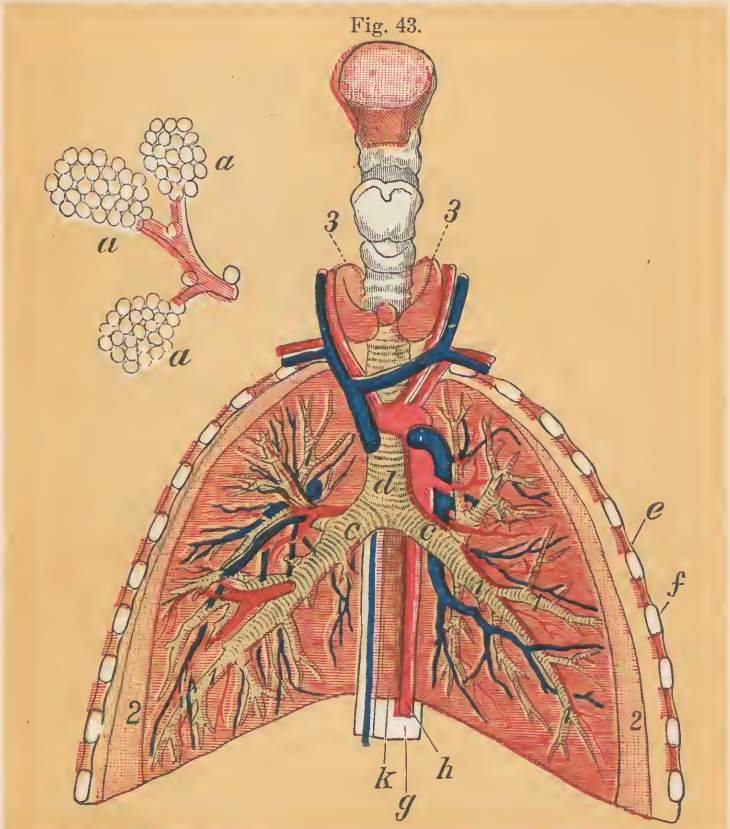
13. Below the larynx is the **trachea** or windpipe, a tube about $4\frac{1}{2}$ or 5 inches in length and $\frac{3}{4}$ of an inch in diameter, flattened on its posterior surface (4, 4, 4, Fig. 42). It is composed of connective tissue and some muscular substance, enclosing from sixteen to twenty cartilaginous bands or rings, which extend only around the anterior two-thirds of the tube, the posterior third containing no cartilage, but made up entirely of connective tissue and muscular fibres. The trachea and all its divisions are lined by mucous membranes and covered with epithelial cells. The mucous membrane contains many mucous glands, which moisten the inner surface of the tube; and the epithelial cells have little hair-like processes on their extremities called *cilia*, which are constantly moving from within out, and tend to clear the tube of any excess of secretion.

14. The trachea divides into two branches called *primary bronchi*, one for each lung. The right bronchus is shorter, wider, and more horizontal in its direction than the left. The bronchi present nearly the same anatomy as the trachea: they enter the lungs, divide and subdivide, becoming smaller and smaller, until they open into a collection of air-cells called a pulmonary lobule, when they measure one one-hundred and twenty-fifth to one one-hundredth of an inch in diameter (Fig. 43, *b*, *b*, *b*, and *c*, Fig. 44).

15. After entering the lungs the character of the cartilages in the bronchi changes. They become plates,

and completely surround the tubes. In very small tubes the cartilages are lost entirely.

Fig. 43.



a, *a*, *a*, pulmonary lobules; *c*, *c*, bronchi; *d*, trachea; *e*, intercostal muscles; *f*, ribs cut across; 1, 1, 1, 1, 1, divisions of the bronchi; *g*, vertebral column; *h*, aorta; *k*, œsophagus; 3, 3, thyroid gland. The arteries and veins are also seen ramifying and dividing.

16. The **lungs** fill all the space in the thoracic cavity not occupied by the heart and large vessels coming

from it. They are suspended freely, and are not attached to the bony wall in any part of its course (Fig. 41).

17. When distended the lungs are roughly pyramidal in shape, with their concave bases down and their rounded apices up; they are covered by a delicate membrane called the *pleura*, which secretes a liquid, that the motions produced by the respiratory acts may take place without friction. Inflammation of this membrane produces pleurisy (*a*, *a*, Fig. 40; 3, 3, Fig. 41; 2, 2, Fig. 43).

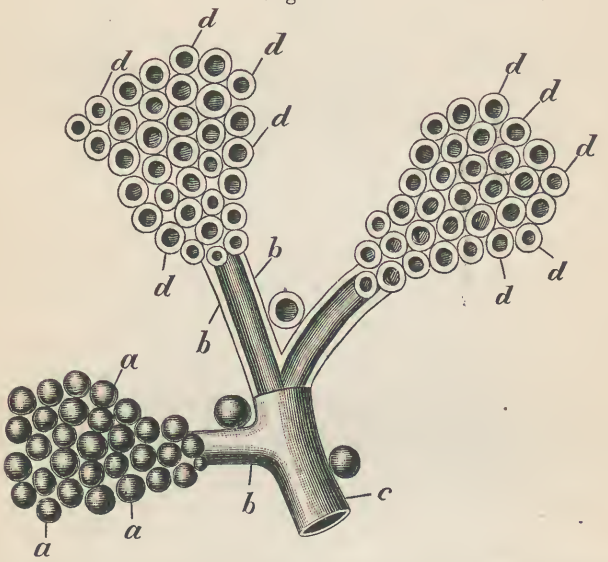
18. The lungs are two in number—*right* and *left*. The right lung has three lobes, and the left lung two (Fig. 40). Each of these lobes is made of lobules which are about $\frac{1}{40}$ to $\frac{1}{2}$ of an inch in diameter, and the lobules are made up of collections of air-cells or vesicles which vary in size with age and in different parts of the lung. They are smaller early than late in life, and are larger nearer the surface than in the deeper parts. Their diameters vary from $\frac{1}{200}$ to $\frac{1}{75}$ of an inch. They are a little deeper than broad, and the anatomy of one of these air-cells is the anatomy of all the cellular part of the lung (*a*, *a*, *a*, *a* and *d*, *d*, *d*, *d*, Fig. 44).

19. The walls of the air-cells are richly supplied with yellow elastic tissue, which, when we come to study the respiratory acts, we will learn performs a very important function in expiration. The fibres of this tissue cross the air-cells in such a way that when one fibre contracts it acts upon more than one air-cell.

20. Interwoven with the yellow elastic tissue is a rich plexus of blood-vessels put very closely together. These are the capillaries of the lungs, provided with one thin coat.

21. The air-cells are lined with thin flattened cells of epithelium which touch the capillary blood-vessels. The air-cells contain the air from the divisions of the bronchi; they are lined with epithelium and surrounded with capillary blood-vessels. The air in the

Fig. 44.



TO REPRESENT THE TERMINATION OF A SMALL BRONCHIAL TUBE AND THREE COLLECTIONS OF AIR-CELLS.

a, *a*, *a*, air-cells; *d*, *d*, *d*, *d*, same cut in two; *c*, small air-tube; *b*, *b*, *b*, divisions of the same, with two represented as being split.

air-cells is separated from the blood in the capillaries on their walls by only two very thin layers of cells, the one forming the lining of the air-cell, the other constituting the wall of the capillary blood-vessel. Here we have again all that is necessary for respiration—air on

one side and blood on the other side of a permeable membrane.

22. The cells are united to form collections and lobules. The lobules are held together by connective tissue to form lobes, and the lobes—three for the right and two for the left—are held together to constitute the lungs. The weight of the lungs is forty-two ounces, the right weighing two ounces more than the left, which weighs twenty ounces.

23. The exact area presented by the air-cells of the lungs is not known, but when it is remembered that the air-cells are microscopic in their size, it will appear that the total area is very great. Different writers have given various estimates, ranging from 150 to 1500 square feet. The air-cells of the lungs of a toad can be seen with the unaided eye, but the air-cells of the lungs of man require the powers of the microscope for their examination.

SECTION III.

1. **Air** enters the lungs through the mouth, nose, larynx, trachea, bronchi, and their subdivisions in consequence of enlargement of the thoracic cavity.

2. This enlargement is made possible by the peculiar method of attachment of the ribs to the vertebral column and sternum, and by the action of muscles.

3. The **ribs** are attached to the dorsal vertebræ by a movable articulation; and their general direction is from behind downward, forward, and inward. The first rib is nearly horizontal in direction; that is, its anterior end

is nearly or quite on a level with its posterior end, while in the ribs below the anterior extremity is on a plane lower than the posterior. This condition is most distinctly marked at the ninth rib. The ribs are also slightly twisted upon themselves. The seventh is the longest, and the first is the shortest rib.

4. The ribs are classified as long flat bones, and are so placed that their surfaces look in and out and their borders up and down. The borders are marked by ridges which serve to protect vessels and give attachment to muscles.

5. Between the ribs are spaces, extending from the sternum in front to the vertebral column behind. These are called *intercostal* spaces and vary in length and breadth in different regions. They are wider in front than behind (*e*, Fig. 43).

6. To the borders of the ribs the external and internal intercostal muscles are attached (*e*, Fig. 43). Muscles are also attached to the posterior part of the ribs which come from the transverse processes of the dorsal vertebræ (*levatores costarum*). The first rib has two muscles, which come from the transverse processes of all the cervical vertebræ except the first and second (*scalenus anticus* and *scalenus medius*). The second rib also has a muscle attached to its outer surface, which comes from the transverse processes of the fifth, sixth, and seventh cervical vertebræ (*scalenus posticus*), and to the whole of the circumference of the base of the thoracic cavity the diaphragm is attached.

7. During ordinary inspiration the diaphragm descends, and the ribs are raised by the action of the above muscles (the sternal portion of the internal inter-

costals being the only part of these muscles which act in inspiration). This enlarges the thoracic cavity in all directions, increasing its vertical, transverse, and antero-posterior diameters. The lungs follow the movements of the thoracic walls, the air rushes in to prevent a vacuum, and the air-cells become distended. This act (inspiration) is active in man.

8. In extraordinary acts of inspiration, as during an attack of asthma, other powerful muscles which are attached to the vertebral column, scapula, sternum, ribs, and humerus are brought into play to assist in elevating the ribs.

9. During expiration the diaphragm becomes relaxed and ascends, while the ribs descend. This diminishes all the diameters of the thoracic cavity, and the lungs not only become compressed, but by virtue of the yellow elastic tissue in their walls the air-cells contract and aid in expelling the air. In man expiration is a passive act.

10. During ordinary expiration a few poorly-developed muscles act. These are portions of the internal intercostals, *infracostales*, and *triangularis sterni*.

11. During prolonged or forced expiration the flat muscles of the abdomen (internal and external oblique and transversalis) contract with power, assisting in drawing down the ribs and pushing up the diaphragm. This action is well shown in blowing a wind instrument.

12. The lungs are of a light pink color in early life, but become darker, and are of an ash-gray or slate color in advanced life; they are also mottled with black, which is due to the deposition of carbon in their substance. This black condition is found in the lungs of

those who spend a great part of their time in an atmosphere of smoke and coal-dust, and hence are constantly inhaling particles of unburnt carbon, which become lodged in the lung-tissue. When this accumulation of coal-dust is so great as to interfere with the function of the lungs, a disease called *anthracosis* is produced. This kind of lung is especially marked in coal-miners.

13. To the touch the lungs are velvety and smooth, and when pressed upon there is a crepitation, or crackling sound, caused by the escape of air from some of the air-cells. They are also elastic, and when removed from the thoracic cavity will collapse. Healthy lungs will float in water, and if pushed under will rise again to the surface. This is of importance in certain medico-legal questions.

14. The important gases concerned in respiration are oxygen and carbonic acid gas. The oxygen which gains access to the blood in the capillaries of the lungs comes from the atmospheric air which is in the air-cells, where it exists as a mechanical mixture, mainly with nitrogen. A small quantity of carbonic acid gas and some vapor of water are always present in the atmosphere. The oxygen and nitrogen exist in the ratio of 20.9 to 79.1 by volume. The amount of moisture is very variable. The quantity of carbon dioxide ranges from 0.0004 to 0.0006. It is greater in the atmosphere of crowded cities than in the open country (*Loomis*).

15. The oxygen is taken from the lungs by the red blood-corpuscles, the coloring matter of which (*hæmaglobin*) has a great affinity for this gas, and is carried to the tissues for respiration. The oxygen unites with the hæmaglobin to form oxyhæmaglobin.

16. The tissues have a greater affinity for the oxygen than the coloring matter of the red blood-cells, and have the power to take this gas from the red blood-cells and use it in the processes of nutrition. When the tissues consume oxygen, they produce some carbonic acid gas. This is mainly taken up by the plasma or liquid portion of the blood, though some of it is taken up by the red cells.

17. The blood carries the carbon dioxide to the capillaries of the lungs, where it goes through the delicate walls of these vessels and mixes with the air in the air-cells, while the oxygen of the air goes into the capillaries to unite with the hæmaglobin of the red blood-cells.

18. The carbon dioxide exists in the blood in simple solution in the plasma, and also to some extent in combination with bases to form salts—carbonates and bicarbonates; that which is in solution simply diffuses from the blood into the air, while the salts are probably destroyed by some other acid uniting with the base and liberating the carbon dioxide. A small quantity of free acid probably always exists in the lungs (pneumic acid), which is destroyed in breaking up salts to liberate CO_2 (carbon dioxide). That carbonic acid gas which is taken up by the red blood-cells is probably liberated by the oxyhæmaglobin, which acts as an acid.

19. Carbon dioxide is not poisonous in the presence of sufficient oxygen, and those gases which are so dangerous to life are such as have so strong an affinity for the red blood-cells that even in the presence of oxygen they retain their position. Among these, the most important is carbon monoxide. Carbon monoxide cannot

be used by the tissues, and as it prevents oxygen from entering into the red blood-cells, asphyxia is produced, which soon ends in death.

20. The stifling atmosphere of a poorly-ventilated and crowded room is not due so much to the presence of carbon dioxide as to the absence of oxygen and the presence of various organic emanations.

21. The quantity of air consumed in twenty-four hours is between three and four hundred cubic feet. The volume of oxygen consumed is not far from $\frac{1}{20}$ of the volume of air inspired. In hospitals and places of public gatherings at least six to eight hundred cubic feet should be allowed for each person, and as much more as possible, unless facilities are convenient for the frequent change of the air.

22. A certain quantity of oxygen consumed is not represented by the carbon dioxide exhaled. It probably unites with hydrogen to form water in the body.

23. Age, sex, exercise, digestion, and sleep all modify the quantity of oxygen consumed and the amount of carbon dioxide exhaled.

SECTION IV.

1. The quantity of air which remains in the lungs after a forced expiration is called the *residual* air, and is about 100 cubic inches.

2. The quantity of air which remains in the lungs after an ordinary expiration is 200 cubic inches, 100 cubic inches of which can be expelled by a forced expiration; this 100 cubic inches is the *reserve* air.

3. The air which goes in and out with each respiratory act is called the *tidal* or *breathing* air. It is simply sufficient in quantity to fill the trachea and larger divisions of the bronchi, and is estimated at about 20 cubic inches.

4. The air which can be taken into the lungs and air-passages after an ordinary inspiration by a forced inspiratory act is called the *complemental* air, and is 110 cubic inches.

5. The quantity of air which can be expelled after a forced inspiration is 230 cubic inches, and represents the breathing capacity of the lungs. The extreme capacity of the lungs must include the residual air, which will make 330 cubic inches.

6. The number of respirations in health is from sixteen to twenty per minute. This number varies, however, even within the limits of health. The number of respirations increases with the increased frequency of the heart-beat, there being generally four beats of the heart to one respiratory act.

7. The respirations are more frequent in early than in adult life. They also increase in frequency in old age. Early in life there is no difference in the frequency of the respirations in the sexes. In women they are less frequent than in men of the same age.

8. Physiologists describe different types of respiration, of which there are three—*superior costal*, *inferior costal*, and *abdominal type*.

9. The abdominal type predominates in young children, and if observed while breathing the abdomen will be seen to move with each respiratory act. This type, combined with the inferior costal, predominates in the

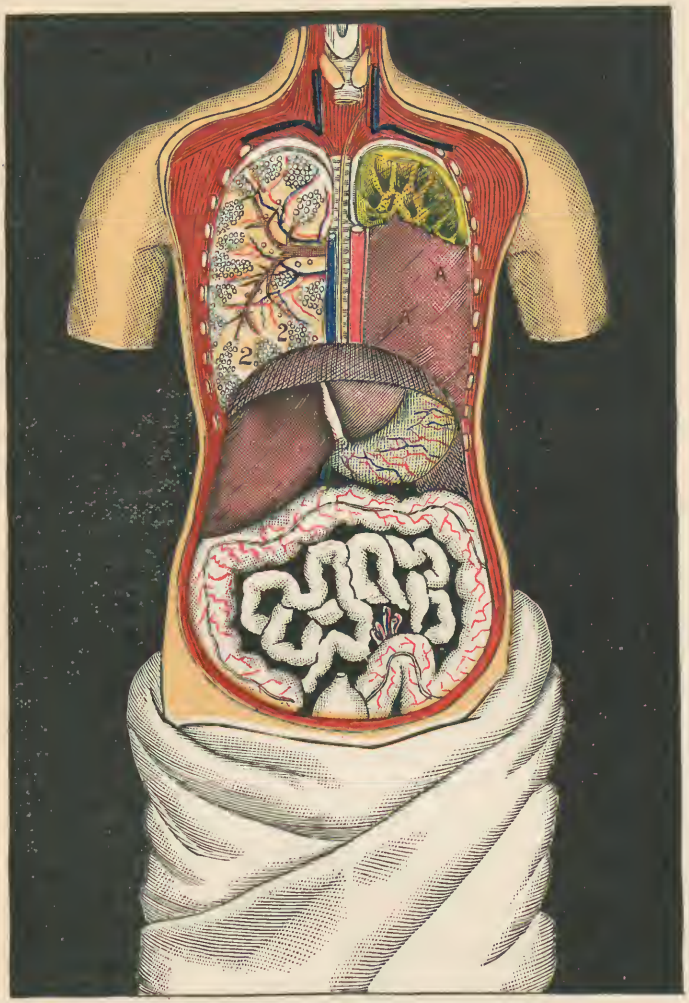


FIG. 45.—*A*, *A*, solidified lung as it occurs in pneumonia, above which at 1 is represented cavities due to abscesses; 2, 2, shows air-cells containing air. The ramifications of the bronchial tree and vessels are also shown.

male. In the female the superior costal type predominates, and the upper part of the breast is seen to fall and rise with each respiratory act. This is probably caused by lacing, which confines and limits the action of the abdominal muscles and the play of the lower ribs. In the females of savage tribes, who have never worn tight clothing, the abdominal type predominates.

10. The lungs act to some extent as excretory organs, eliminating, in addition to carbonic acid gas, a small quantity of the vapor of water, organic matter, and a trace of ammonia.

11. When alcohol is taken into the system a portion of it is eliminated by the kidneys, skin, and lungs, the greater part being consumed in the tissues by oxidation. When large quantities have been ingested the kidneys are relatively active in elimination. When small quantities have been taken, the lungs are relatively more active in its elimination than when large doses have been ingested. The habitual use of alcohol produces congestion and inflammation of the lung-tissue, leading to pneumonia and consumption (Fig. 45).

12. In order to properly perform their function the air-cells should be supplied with a sufficient quantity of pure air, which can be accomplished by regular and deep breathing in a pure atmosphere. Deep inspirations not only more perfectly change the air in the deeper portions of the lungs, but distend the air-cells, favor the absorption of any exudation that might be in them, and increase the surface of blood-vessels exposed to the air. They also facilitate the circulation in the liver.

13. The walls of the thorax and abdomen should not be restricted in their natural movements by the appli-

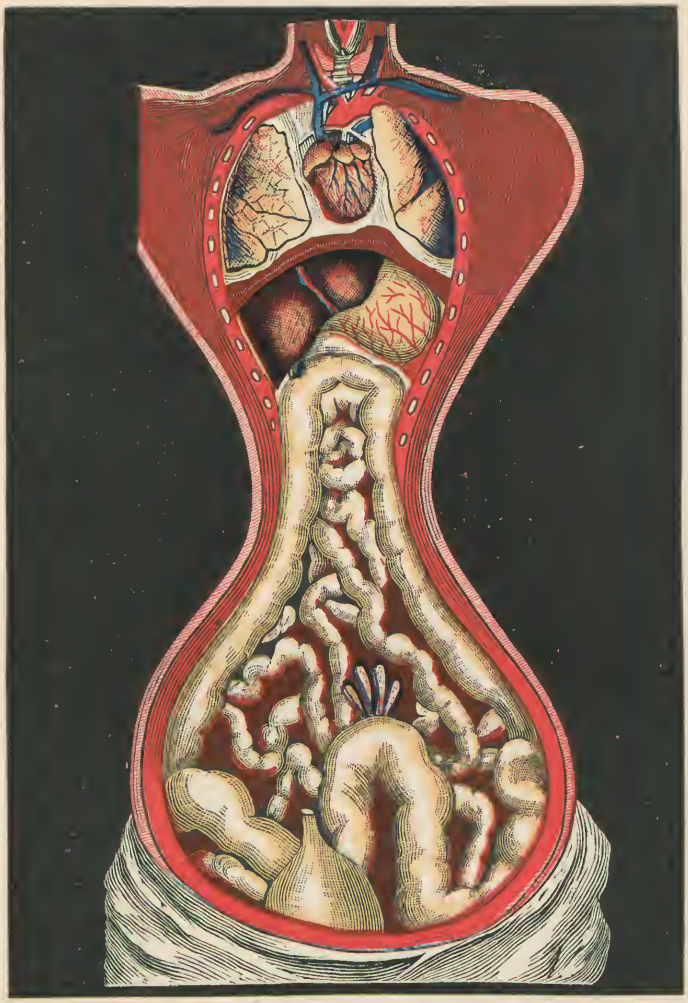


FIG. 46.—Diagram designed to show the effects of tight lacing in early life, resulting in permanent deformity of the thoracic walls. Compare with Figs. 45 and 41, which are normal.

cation of tight articles of clothing. The lungs follow the movements of the diaphragm and thoracic walls, and when these are interfered with the lungs are unable to become distended, the air-cells are not properly inflated, the air is not sufficiently changed in the deep portions of the lung, the blood cannot be properly oxidized and purified, and the nutrition of all the tissues must suffer (Fig. 46).

14. In order that the lungs may play with ease in the cavity of the thorax, the body should be kept erect and the shoulders thrown well back. This position facilitates the action of those muscles concerned in modifying the dimensions of the thoracic cavity, and enables the air to enter the respiratory passages at the best possible advantage.

QUESTIONS.

SECTION I.

What is respiration ?(1). What are the lungs ?(2). What must tissues have in order to perform their function ?(3). What change takes place in the tissues when they work? Where does the blood lose its poisonous gas, CO_2? and where does it gain oxygen ?(4, 5). Are the changes concerned in the formation of CO_2 in the tissues well known ?(6). Do all animals need oxygen? Do the tissues need it constantly ?(7). Describe the change which takes place as the blood passes through the lungs. What change takes place as it passes through the tissues of the body? Is the composition of the arterial blood the same in all divisions of the vascular system? Is the venous blood the same in structure in all veins ?(8).

SECTION II.

What kind of organs are the lungs? What is their function ?(1). What takes the place of lungs in the simplest animals? Describe the respiratory organs of some of the lower animals. What kind of struc-

ture is necessary in a breathing organ?(2). What is the structure of the lungs of amphibians? of birds and mammals?(3). Into how many cavities is the belly cavity of man divided? What muscle divides it? What are the divisions called? What does each cavity contain?(4). Bound and describe the thoracic cavity(5, 6). What is the shape of the diaphragm during the respiratory acts?(7). Where is the opening into the larynx?(8). What is the larynx? What important structures does it contain? Describe the vocal cords. Which are the true cords? (9). What is the rima glottidis? What enables the cords to move? (10). What is the condition of the slit during the respiratory acts?(11). What closes the entrance to the glottis? What is its position during the acts of breathing? What does it do during the act of deglutition?(12). Describe the trachea(13). Describe the bronchi(14, 15). Where are the lungs situated? Are they attached to bone?(16). What is their shape when distended? What covers them? What is the function of the pleura? What is pleurisy?(17). How many lungs are there? Describe their structure(18). Describe the structure of an air-cell(19–21). Describe the formation of a lung from the air-cells. What is the weight of the lungs?(22). How much surface is presented by the air-cells of the lungs of man? Can the cells be seen with the unaided eye?(23).

SECTION III.

What causes the air to enter the lungs? What causes this enlargement?(1, 2). Describe the attachment and direction of the ribs(3). How are the ribs classified? How do their borders and surfaces look? (4). Describe the intercostal spaces(5). Describe some of the muscular attachments to the ribs(6). Describe the changes of the thoracic cavity during ordinary inspiration, and the action of some of the muscles concerned. Do any additional muscles act during extraordinary inspiration?(7, 8). Describe the changes of the thoracic cavity during expiration. What is the condition of the air-cells at this time?(9). What muscles act during ordinary expiration? What muscles act during forced and prolonged expiration?(10, 11). What is the color of the lungs in early life? in old age? Name some causes of discoloration of lung-tissue(12). How does lung-tissue feel to the touch? What causes the peculiar sound when it is pressed upon? Will healthy lung-tissue float in water?(13). How does the oxygen exist in the air-cells? Give the relative quantities of nitrogen and oxygen in the atmospheric air. Does the air contain any CO_2?(14). How does the oxygen reach the

tissues? What is the union of oxygen and the coloring matter of the blood called?(15). Why does the oxygen leave the blood and go to the tissues? What kind of gas do the tissues produce when they use oxygen? How is this gas taken up by the blood?(16). What does the blood do with the (CO_2) carbon dioxide? What gas then enters the blood?(17). How does the carbon dioxide exist in the blood? How is that which exists as bicarbonates, etc. liberated in the lungs?(18). Under what conditions are gases poisonous and dangerous to life?(19). What causes the poisonous gases of poorly-ventilated apartments?(20). How much air is consumed in twenty-four hours? How much oxygen? How many cubic feet should be allowed for each person in crowded public buildings?(21). Is all the oxygen consumed represented by the CO_2 exhaled? What becomes of the lost oxygen?(22). Name some things that modify the quantity of oxygen consumed(23).

SECTION IV.

What is the residual air? How much is it?(1). What is the reserve air? its quantity?(2). What is the tidal air? its quantity?(3). What is the complemental air? its quantity?(4). What is the breathing capacity of the lungs? What is the extreme capacity of the lungs?(5). How many respirations per minute in health? How many beats of the heart to one respiratory act?(6). How do the respiratory acts vary in frequency at the different ages of life? Are they more frequent in the male or female?(7). How many types of respiration are there? Name them(8). Describe these types. What probably causes the superior costal type in females? What is the type of breathing in the females of savage tribes?(9). Name some substances thrown off by the lungs. (10). What becomes of alcohol when taken into the system? What dangerous changes are induced in the lungs by its excessive use?(11). How can the air-cells be furnished with pure air? Name some advantages of deep inspiration(12). Describe the effects of tight lacing on the shape of the thoracic cavity, and its dangerous effects on respiration (13). What should be the position of the body in order that the respiratory acts may take place to the best advantage?(14).

CHAPTER VII.

MUSCLES.

SECTION I.

1. **Muscles** may be defined as the active organs of locomotion, the bones, especially those of the extremities, being the passive organs of locomotion.

2. Animals are enabled to move from place to place in quest of food and to perform work by the action of the muscles upon their bones. But animals very low in the scale of life also have the power of motion, though they have no muscles at all. In these, however, the motion is due to the contraction of the protoplasm of which they are composed, the simplest forms sending out portions of the body which act temporarily as feet. Those forms a little higher in the scale have parts of their structure modified into little hair-like processes on their surface called cilia, which move all in one direction, and faster in one direction than in another, thus enabling the animal to move through the water, or, when its body remains at rest, creating currents in the water which may bring it food.

3. It is only in the higher divisions of the animal kingdom that distinct muscular tissue makes its appearance. In the lowest forms of life all parts, or any

part, of the body perform any or all functions necessary to the existence of that form of life; but in higher animals certain parts perform certain functions or do certain work for all other parts, whereby they are exempted from doing many other things that are necessary for the existence and life of the animal to which they belong.

4. In the simplest animals any part of the body can feel, move, secrete, excrete—in a word, do anything that is necessary to be done—but in the highest animals certain parts are concerned with sensation alone (*nerves*), and have nothing to do with motion (except to stimulate the muscles); other parts are concerned with motion (*muscles*), and do no part of the work of nerves; and still other parts are for support and protection (*bones*), and have nothing in common, so far as function is concerned, with either nerves or muscles. Of course, in higher animal life the integrity of structure and function of every part depends upon the presence and healthy action of all other parts; that is, bones could not assist in locomotion unless the muscles were normally active, and muscles could not properly act unless the bones (or their equivalents) and the nerves were performing their duties properly.

5. All animals that have muscles are not supplied with bones, yet they have certain parts peculiarly developed to receive the insertion of the muscles, and which, so far as locomotion is concerned, take the place of bones. This is the case in those invertebrates whose external parts are developed into hard crusts or shells, as the lobster, crab, bee, etc., the muscles being attached to the inner surface of the shell or crust, which is a

modified skin, and which is called the exoskeleton. It serves for protection as well as for muscular attachment.

6. *Contractility* is one of the properties of muscular tissue, and when the fibres of a muscle undergo contraction, the two ends approach the centre and they become thicker and shorter. This power to contract is one of the fundamental properties of protoplasm, like sensibility and the power to appropriate food for growth and the ability to reproduce its kind in a new form. Just why protoplasm, or its special modification muscular tissue, contracts, no one has as yet explained. All that can be said in this direction is, that under certain conditions muscular tissue will behave in this peculiar manner. It is just as wonderful that muscular tissue should contract as that nervous tissue should generate and transmit nervous force.

7. Contractility, then, is one of the so-called phenomena displayed by muscular tissue. This contraction, or shortening and thickening, of muscular fibres can be induced in a variety of ways—by the application of mechanical or chemical stimuli, as acids, alkalies, cold, heat, or direct injury by a blow; by the passage of electricity through their substance or the nerves that supply them. The cause generally given for muscular contraction is the transmission through their nerves of some influence generated by the cellular matter of the brain. Still, muscular tissue will respond, for a time, by contraction to the application of a stimulus when entirely separated from the nervous system, showing that it has an irritability of its own.

8. This is shown in an admirable manner when the heart of an animal is suddenly extirpated: though re-

moved from all connection with the central nervous system, yet the heart keeps up its contractions spontaneously for a time—that is, without the application of a stimulus, unless the air be considered as such—and after these spontaneous actions have ceased, contractions can be induced by simply pricking the surface of the organ with a pin. This can be done again and again, the heart at first responding by several contractions to each application of the stimulus, until finally each prick of the pin provokes but one contraction, and later no contraction at all.

9. After the external application of the stimulus fails to elicit a response, the heart may be made to contract by pricking or simply sticking its internal surface. This continues for a time, when the organ ceases altogether to respond to a stimulus applied either externally or internally. If it now be allowed to rest for a time, and especially if it be bathed in blood, it regains to some extent its powers of contraction; but a time comes when no treatment can induce a contraction in the dead muscle, and physiologists say it has lost its "chemical and physical integrity;" which means no more than that those changes which take place in its substance by which it is enabled to produce the phenomenon of motion no longer occur, and that it dies because it is not in a condition for these changes to take place.

SECTION II.

SUBDIVISIONS OF THE MUSCLES.

1. Muscles vary in color in different animals. Generally they are white in cold-blooded animals, such as fishes, frogs, and reptiles, and red in warm-blooded animals, as birds and mammals. There is an exception to this in the muscles of the breast of the partridge, pheasant, common fowl, etc., which are white. The muscles of the spider are yellow. The muscles in man are red, and this is true of all the animals of the class to which he belongs.

2. Muscles are divided into *smooth* and *striated* muscles. Generally speaking, all the muscles of the insect tribe and the voluntary muscles of animals possessing a backbone are striated, while the involuntary muscles are non-striated or smooth.

3. **Voluntary or striated muscles** are those that are under the influence of the will; they are presided over by the cerebro-spinal nervous system, and can be called into action at any time. The greater number of the muscles of the body are of this variety, especially the muscles of locomotion. By an act of the will we can flex and extend the forearm, run, jump, or walk. Such actions are called voluntary, and are executed by voluntary or striated muscles.

4. **Involuntary, non-striated, or smooth muscles** are those that are not under the influence of the will; they are stimulated to action and governed by the sympathetic nervous system, and it is impossible to influence their action by any force of the will. Such muscles are found in the arteries and veins, iris of the eye,

walls of the alimentary canal (œsophagus, stomach, small and large intestines). The iris is the muscular curtain suspended behind the cornea and in front of the most important refracting media of the eye. It presents in its centre the opening called the pupil (sometimes called the sight), which increases and diminishes in size with the varying amount of light it receives. It contracts and becomes small when exposed to a bright light, and in the dark it dilates and becomes large. It governs the amount of light admitted to the eye. It is impossible by an act of the will to directly influence the movements of the iris. The iris also receives filaments from the third nerve (*motor oculi*).

5. The various parts of the alimentary canal move during digestion, and it is impossible, for example, to regulate the movements of the stomach, induced by the presence of food, by any direct act of the will. So the blood-vessels vary in their size in obedience to the demands of nutrition, yet no act of the will can modify their diameter.

6. The heart, though involuntary in its action, resembles voluntary muscular tissue in that it is striated, though it differs from it in other points of structure—in possessing no sarcolemma, and in the inosculation and branching of its fibres and central position of the nuclei.

7. There are certain muscles in the human body which generally have an involuntary action—muscles of respiration—but which can be arrested for a certain time by an act of the will. Normally, when we breathe the diaphragm contracts and relaxes without attracting our attention, but if we desire we can by an act of the

will cease to breathe for a time, and the diaphragm ceases its action. It is impossible, however, for us by any direct act of the will to cause the heart to cease its pulsations. Muscles like those of respiration may be called, so far as their action is concerned, *mixed* muscles.

8. There are certain muscles in the human body which may be called *hollow* muscles: they contain a cavity. Such are the heart, arteries, stomach, intestines, and bladder. There are other muscles which surround openings into the body, and which are sometimes called hollow muscles: they are more properly described as *flat* muscles arranged in a circular or oval manner. Examples of muscles of this kind are to be found surrounding the eyes (*orbicularis palpebrarum*), mouth (*orbicularis oris*), and the extremity of the large intestine called the *rectum*, which is closed by the external *sphincter ani* muscle (Fig. 47).

9. **Hollow** muscles have no attachment to bone, the heart, for example, being held in place by the large vessels coming from its base. The sphincter muscles that close the mouth and rectum have no bony attachment, while the muscle closing the eye has a bony origin (Fig. 47).

10. The greatest number of muscles are attached to bones, and are under the influence of the will. There are other muscles under the control of the will attached to the skin, but they are poorly developed. Among muscles of this kind may be mentioned the *occipito-frontalis* (which enables us to move the scalp and to raise the eyebrows); the three muscles of the ear, which belong to the same class, and can be moved by some people; the flat *platysma-myoides*, occupying the side of

Fig. 47.



MUSCLES OF HEAD, NECK, FACE, AND EAR.

1, 1. 1, muscles of the ear; 2, 2, the bellies of the occipito-frontalis; 3, orbicularis palpebrarum; 4, orbicularis oris; 5, sterno-cleido mastoid; 6, trapezius; 7, 7, 7, 7, fascia covering the temporal muscle.

the neck and blending with many of the facial muscles, which can be used by many persons in shaking or twitching the skin in this region. Nearly all of these muscles have some bony point of attachment; they are very poorly developed in the human subject, and are often spoken of by anatomists as rudimentary muscles (Fig. 47).

SECTION III.

PHYSICAL CHARACTER OF THE MUSCLES.

1. The **weight** of the muscles is more than three and a half times the weight of the bones, and the **bulk** of the muscles is more than six times the bulk of the bones. The bones in the recent state of a person of medium weight weigh about twenty-two pounds.

2. Muscles are generally attached to bones through the medium of the *periosteum* and tendons or *aponeuroses.*

3. The **periosteum** is the name of the membrane which surrounds all bones except at their articular surfaces. **Tendons** are bundles of fibrous connective tissue terminating a muscle. **Aponeuroses** are flattened tendons.

4. Muscles form the great bulk of the body, and in addition to assisting in locomotion they act as easy cushions or chairs protecting the bones from direct external violence.

5. The voluntary as well as the involuntary muscles present a great variety in shape and in the arrangement of their fibres, as well as in their size and strength.

6. The smallest muscle in the human body is probably in the middle ear (*stapedius*). It is said to be about

one-sixth of an inch in length and to weigh not more than one grain. The longest muscle is probably the *sartorius*, which runs from the sharp point at the anterior part of the hip (*anterior superior spinous process of the ilium*) to the upper and front part of the tibia, or leg-bone, below the knee. It crosses the anterior part of the thigh from without inward, and is about two feet long (Fig. 48). Among the largest muscles may be mentioned the *gastrocnemius*, which forms the bulk of the calf of the leg, the *deltoid*, which forms the prominence of the shoulder externally, and the *glutei* muscles, which form the larger part of the nates (Fig. 48).

7. Some muscles have their fibres running parallel with each other from their origin to their insertion. Such muscles are said to be straight.

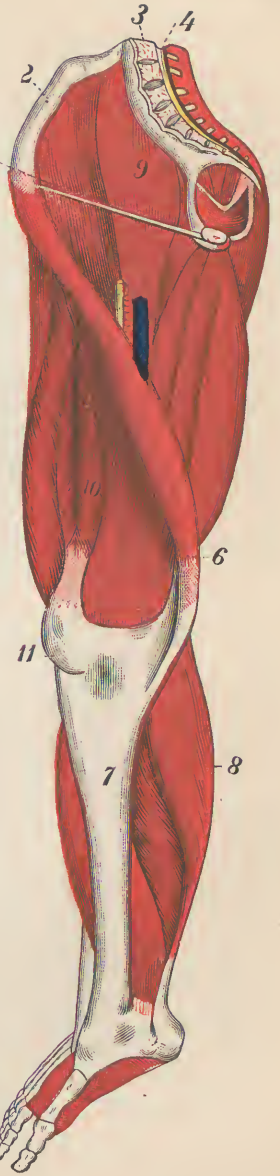
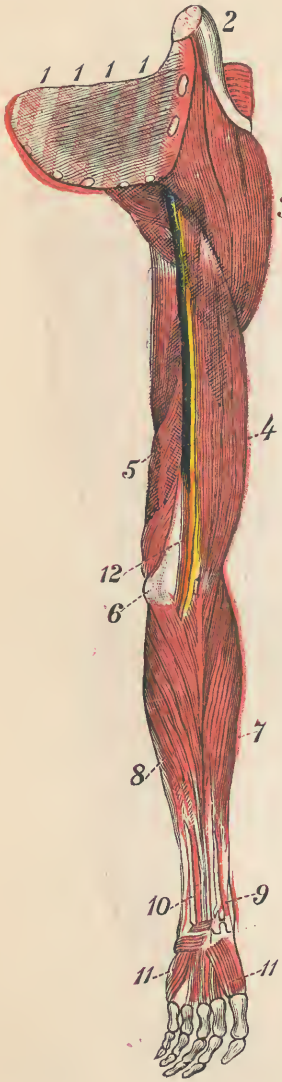


FIG. 48.—1, Poupart's ligament; 2, crest of the ilium; 3, bodies of vertebræ cut through vertically; 4, spinal canal laid open; 5, gluteal muscle; 6, sartorius; 8, gastrocnemius; 9, psoas (mg) muscle; 10, bipenniform, rectus muscle; 7, tibia. The sartorius is seen crossing the femoral vein, blue; artery, red; ant. crural nerve, yellow; 11, patella.



In others the fibres have a fan-shaped arrangement; that is, they arise from a relatively great surface, and all converge to one relatively small surface for attachment. This variety is called radiate. In still others the fibres of the muscle bear the same relation to parts of their tendons that the vane (barbs and barbules) bears to the shaft of a feather. Such muscles as these are called *penniform* if the arrangement is on one side, and *bipenniform* if on both sides (Fig. 48).

8. By applying the hand to the side of the head and firmly pressing the teeth of the lower jaw against those of the upper jaw, the action of the temporal muscle can be felt and its radiate form distinguished. It presents a broad circular base above, gradually converging as it descends to be

FIG. 49.—LEFT ARM ANTERIOR VIEW, SUPERFICIAL MUSCLES OF THE SHOULDER, ARM, FOREARM, AND HAND.

1, 1, 1, ribs; 2, part of the clavicle; 3, deltoid; 4, biceps, inner head of the triceps; 6, internal condyle of the humerus; 7, 8, muscles of the forearm; 9, radial artery; 10, ulnar artery; 11, 11, muscles of the hand; 12, brachial artery.

attached to a process (*coronoid*) of the inferior maxillary bone.

9. Muscles are named from their size, as, *magnus, medius, minimus, parvus, longus, brevis*, etc.; also from their shape, as, *triangularis, quadratus, rhomboideus;* from their direction, as, *rectus, obliquus;* from their position, as, *internus, externus, lateralis, superior, inferior, anterior, posterior;* from their attachments, as, *sterno-hyoid, sterno-cleido-mastoid, coraco brachialis, omo-hyoid;* from their action, as, *flexors, extensors, adductors, abductors, supinators, pronators, in-rotators* and *out-rotators* (Fig. 49 and Fig. 50).

10. Muscles are surrounded by bandages of white fibrous connective tissue called **fascia**, the function of which is to separate muscles and groups of muscles from each other, to afford surface for muscular origin or insertion, and to bind the muscles to the bone and to each other, that they may act to the best possible advantage.

11. Every **group** of muscles has its proper investing fascia, which is a common investing membrane for all the muscles of that group: from the under surface of the common envelope of fascia processes are given off which enclose each muscle of the group in its own special sheath, so that if all the muscular substance were dissolved out, a perfect form of the muscles would be left enclosed by the fascia. The fascia not only surrounds the muscles at every point, but frequently seeks attachment to the bone, thereby holding the muscle in position.

12. The fascia which surrounds the muscles is called the *deep* fascia, in contradistinction to a fascia situated under the skin over the greater portion of the body, which is called the *superficial* fascia. The **deep fascia**

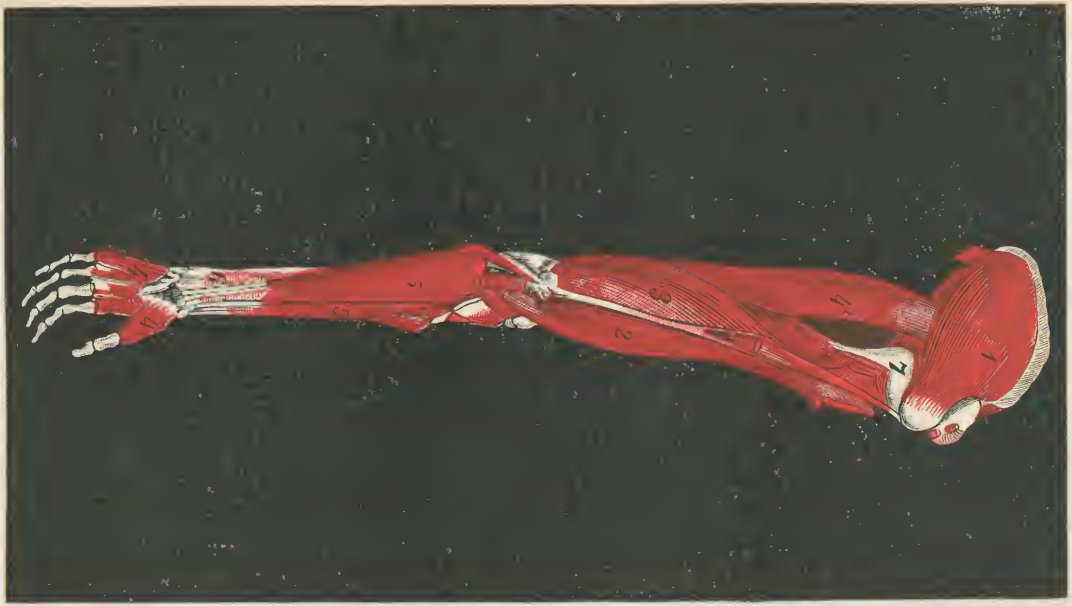


FIG. 50.—OF RIGHT SIDE, SUPERFICIAL MUSCLES REPRESENTED AS CUT AWAY.

1, subscapularis; 2, biceps; 3, outer head of the triceps; 4′, long or scapular head of the same; 5, 5, muscles of the forearm; 6, lower end of the ulna; 4, 4, muscles of thumb and hand (*posterior view*); 7, humerus.

is dense and strong, the fibres of which it is composed being closely and densely arranged. The **superficial,** on the other hand, is composed of fibres which are loosely arranged. It generally exists in two layers, and acts as a nidus or bed in which run blood-vessels and nerves. When its fibrous connective-tissue corpuscles become changed into fat, it becomes very much thicker and acts as a blanket to the body, preventing radiation of heat and keeping it warm. It acts as a cushion upon which the skin rests, and also protects the underlying structures from injury.

13. The voluntary muscles are striated in appearance and fibrous in their structure. If a piece of the muscular part of a beef be boiled and allowed to cool, it will be noticed that it is fibrous in its structure, and these fibres can be easily separated from each other as longer or shorter strings. Each fibre or string thus procured is really composed of a number of anatomical fibres united to each other by delicate connective tissue.

14. By very delicate manipulation small fibres, measuring from one to two inches in length and varying from $\frac{1}{150}$ to $\frac{1}{500}$ of an inch in diameter, may be obtained, and the power of the microscope is needed for the study of their structure (Fig. 51).

15. Each muscular fibre is rather round or cylindrical in shape, and narrower at either extremity than in the middle part. Surrounding or limiting each fibre is a very delicate membrane of a slightly elastic tissue called the *sarcolemma,* the function of which is to enclose the muscular substance. Inside the sarcolemma, running from one side to the other, are delicate partitions separating or dividing the space enclosed

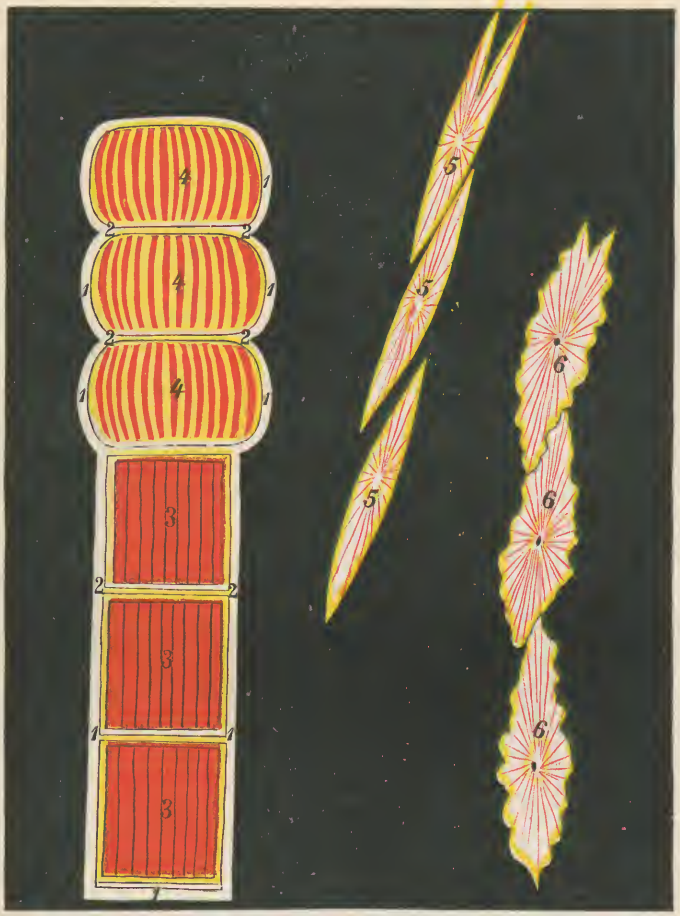


FIG. 51.—DESIGNED TO REPRESENT THE STRUCTURE OF MUSCLE-FIBRES AND CELLS.

1, 1, 1, sarcolemma of a voluntary muscular fibre; 2, 2, 2, point of attachment of the membranes of Krause; 3, 3, 3, chief substance of Rollett. The yellow margin is the secondary substance; 4, 4, 4, shows the muscular compartments in a condition of contraction. The red sarcous elements of Bowman are separated by the yellow secondary substance; 5, 5, 5, involuntary muscle-cells; 6, 6, 6, same in a condition of contraction.

by the sarcolemma into smaller divisions, called *compartments.* These partitions are called the *membranes of Krause,* and the compartments the *muscular compartments of Krause* (Fig. 51).

16. The **membranes of Krause** produce the transverse striations of voluntary muscles. Within these muscular compartments of Krause are situated the active parts of muscular tissue. Each compartment contains two distinct elements, called the *chief and secondary contractile substances of Rollett* (Klein) (Fig. 51).

17. The **chief** substance occupies the greater part of the compartment, the secondary part being confined mainly to the sides of the membranes of Krause. The secondary part is fluid in its nature.

18. The chief substance is composed of a number of rod-shaped bodies arranged in the long axis of the compartments. These are called the *sarcous elements of Bowman,* and are separated from each other by a very small quantity of the secondary substance which is prolonged between them. This is sometimes called the *lateral disc of Englemann.*

19. Thus each fibre is seen to be made up of a number of compartments containing a number of rods superimposed one upon the other. This gives to the whole fibre a longitudinally striated appearance. The rods are called *primitive fibrillæ,* and in studying the formation of an anatomical muscle we see how the fibrillæ are held together to make a fibre (Fig. 51).

20. These fibres, surrounded by their sarcolemma, are held to each other by very delicate connective tissue to constitute a small bundle. A number of these small bundles are held to each other by stronger fibrous con-

nective tissue to form a larger bundle, and these in turn are held together by other connective tissue to constitute an ordinary anatomical musele; and each anatomieal musele is surrounded by its sheet of eonneetive tissue or speeial fascia, and museles are arranged in groups and held together by the eommon investing fascia.

21. The tissue holding bundles together is rather strong and supports the larger vessels and nerves as they run to supply the muscles. The eonnective tissue which holds the very small bundles and fibres together is delicate and supports the smallest divisions of the vessels and nerves. The vessels divide and subdivide in the muscle until they beeome very small and are situated between the fibres: they do not penetrate the sareolemma and enter the interior of the fibre. Museles are nourished, then, by absorption of the material which must escape from the very delicate blood-vessels in their substanee.

22. The small vessels between the ultimate fibres of the muscle are very delicate, and during the action of the musele are subjected to distension as a result of pressure, forcing more blood into them from the larger vessels. This pressure is thought to be sufficient to rupture them were it not for enlargements developed at intervals in their lumen, which aet in emergencies as reservoirs to accommodate the increased amount of blood and to diminish the strain.

23. Muscles have an *origin*, an *insertion*, and an intermediate part which is ealled its *body* or *belly*. The origin is generally spoken of as the most fixed part of the musele; the insertion is applied to the end having the greater range of motion. Museles begin by ten-

dinous fibres from periosteum, from adjoining tendons, and from the fascia which covers them. They are inserted into bone through the medium of periosteum, ligaments, cartilages, and membranes.

24. Muscles are generally tendinous at their origin and at their insertion, and muscular in the intermediate part. Sometimes the muscle ceases abruptly and the tendon begins as suddenly; at other times the change from muscle to tendon is very gradual and indistinct. Where muscles cease suddenly or meet tendons at an angle, their fibres end in conical projections which are received into corresponding depressions in the tendon. Where the change is gradual no such connection is apparent.

25. If the muscular fibres are but from one to two inches in length, and some muscles have a length of two feet, it must appear that the fibres are ceasing and beginning throughout the greater length of the muscle. This takes place by the tapering end of one fibre being overlapped by the tapering ends of other fibres, and held together by the sarcolemma of one being prolonged as a thread to meet the sarcolemma of others, as well as by the connective tissue which is always present.

26. The relative length of the muscle and tendon varies with age. Early in life the muscular part is relatively long; hence the activity and agility of children are greater than of adults, where the muscular part becomes relatively short and the tendinous part long. In some muscles the tendon occupies half the length of the muscle, as in the *semitendinosus* (one of the muscles on the inner and back part of the thigh), which is named from this fact.

SECTION IV.

INVOLUNTARY MUSCLES.

1. **Involuntary muscles** are non-striated, and are cellular rather than fibrous in their structure. They are elongated cells narrower at either extremity than in the middle, and each cell is supplied with a nucleus which undergoes change in shape with the changes produced by the different action of the cell (Fig. 51).

2. Each cell is composed of a delicate sheath surrounding a collection of very small and thin fibrillæ. The sheath bears the same relation to the involuntary cell that the sarcolemma bears to the muscular fibre of voluntary muscles.

3. The direction of the delicate fibres enclosed by the sheath is parallel with the long axis of the muscular cell, and under certain conditions of treatment produces a longitudinally striated appearance in these cells, as the membranes of Krause produce a transversely striated appearance in the voluntary muscular fibres.

4. The delicate fibrillæ are collected into bundles, and are the contractile elements of the cell. The nucleus or kernel occupies mainly a central position, and the fibrils run into and become blended with the substance of its interior (Fig. 51).

5. When the muscular cell is active the fibrils contract from either end toward the nucleus, and tend to bring each end of the cell closer to its central part, thus making the cell shorter and thicker. The cells are held together by a very delicate substance, resembling that which holds together the elementary connective-

tissue fibrils, to form bundles, and finally membranes. They are very short, and measure but from $\frac{1}{20}$ to $\frac{1}{400}$ of an inch in length, though they vary like other tissues in size in different parts of the body. They are supplied with blood-vessels, and are stimulated to action by the sympathetic nervous system.

6. They are found in various parts of the circulatory system (arteries and veins). The heart, though involuntary in its action, as said before, is voluntary in its structure, differing from voluntary muscles in having no sarcolemma for its fibres, in that its fibres branch and inosculate, and in the central position of the nucleus, which in ordinary voluntary muscular fibres is situated immediately underneath the sarcolemma. They are also found in the intestines, stomach, bladder, certain parts of the respiratory tract, kidneys, ureters, uterus, in the ducts of many glands, and in certain parts of some mucous membranes.

7. Voluntary muscles generally respond very promptly when stimulated to action. Involuntary muscles, on the other hand, begin contraction very gradually, continue it for a certain time, and as gradually return to a state of repose.

8. The function of the muscles is to contract and relax in order to facilitate locomotion, secretion, excretion, digestion, circulation, and respiration. Indeed, there are few functions, if any, of the body, properly performed and manifested independent of muscular action. The muscles form the greater part of the body, and by their action probably have much to do in maintaining animal temperature.

9. Muscles need exercise to keep them in a proper

condition for the discharge of their duties; if allowed to remain idle and inactive, they become diseased and degenerated, and finally unable to perform any work. By careful, moderate, and regular exercise the effete matter of the muscular substance is removed, and its place occupied by new and vigorous substance furnished by the blood. Work means decay, and life implies death, and so long as muscles work they produce effete matter, and that part of their substance which is at one time alive and active is soon dead and inert. In order to maintain their normal structure and properly perform their work there must be a constant reception of new material and as constant discharge of old. This can only take place when muscles are engaged in work.

10. Muscles increase in size with increased use, and within certain limits continue to enlarge to meet the requirements imposed upon them; and when one muscle or a set of muscles from any cause becomes weak and small, other muscles become correspondingly enlarged. Violent exercise is not conducive to muscle-growth, but exercise which is beneficial to the muscular as well as to all other systems of the body should be moderate and *regular*. No benefit can be derived from exercise and industry one day, and indolence and inertia the next.

11. It is a matter of great importance to surgeons to know the origin, insertion, power, and action of muscles, that they may be enabled to perform amputations and reduce and treat fractured bones to the best possible advantage to the patient. Muscles also furnish guides in certain operations, as in ligations of vessels, when

they bear a certain relation to the parts to be operated upon, and are called *landmark* or *satellite* muscles. Thus, the radial artery, which produces the pulse at the wrist, lies between two muscles in the lower part of its course. The tendon of the inner one (*flexor carpi radialis*) is very prominent, and may be called one of the satellite muscles of the radial artery, which can be felt pulsating on its outer side.

12. By the play and interplay or action and interaction of muscles and tendons upon each other and upon bones, ligaments, and cartilages it is possible for us to perform all the motions used in locomotion and the varied actions of life.

13. **History.**—A good knowledge of the muscles was possessed by the earliest anatomists who enjoyed the privilege of dissecting. The celebrated physician Galen (who died about two hundred years after Christ) endeavored to teach the mechanism of locomotion by exposing the muscles of an animal by dissection, and demonstrating their action on the bones during the alternate contraction and relaxation of their substance. He classified them according to their uses, and though he omitted many, yet he described and named not a few. The first human anatomists were probably Erasistratus and Herophilus, who flourished in the Alexandrian school of medicine more than four centuries before the birth of Galen. It is recorded of them that they were so desirous of learning the hidden secrets of life that they dissected the living as well as the dead human body; and even Vesalius, who is called the father of anatomy, born as late as 1514, is said to have lost his life in attempting to evade punishment for a similar offence.

QUESTIONS.

SECTION I.

What are muscles? What kind of organs are bones?(1). Describe some methods by which animals move(2). In what kind of animals are muscles found? What is the function of muscles?(3). Tell some points of difference between the simplest and the higher animals. What relation do the different tissues of the body bear to each other? (4). To what are the muscles attached in those animals which have no bones? Name some animals with a covering of this kind. What is this covering called? Why? What other function has it?(5). What peculiar property has muscular tissue? What change takes place in the muscular fibre during contraction? Why does muscular tissue contract?(6). How may muscular contraction be induced? What is the general cause of muscular contraction? Has muscular tissue an irritability of its own?(7). How can this property of muscular tissue be shown?(8). Why does an excised heart fail to respond by contraction to the application of a stimulus to its interior?(9).

SECTION II.

What is the color of muscle in cold- and in warm-blooded animals? What is its color in the spider? in man?(1). Name the classes into which muscles are divided. Where are striated muscles found? Where are smooth muscles found?(2). What are voluntary muscles? What nerves stimulate them? Give examples of some acts executed by this variety of muscular tissue(3). What nervous system presides over the involuntary muscles? Can they be directly influenced by the will? Name some places where they are found(4, 5). Describe the muscular structure of the heart(6). What is peculiar about the muscles of ordinary respiration?(7). What are hollow muscles? Name some(8). Are the hollow muscles attached to bone?(9). Name some muscles that are attached to the skin. What are they sometimes called?(10).

SECTION III.

What is the weight of the muscles?(1). How are muscles attached to bones?(2). What is periosteum? What are tendons? What are aponeuroses?(3). What part of the body do muscles form? What protection do they give to bones?(4). Do muscles present any vari-

ation in size? in shape?(5). What is the smallest muscle in the body? What is the longest muscle in the body? Name some of the largest muscles of the body(6). How do the fibres of muscles run?(7). How may the temporal muscle be made to act? What kind of a muscle is it? Where is it attached?(8). How are muscles named? Give some examples(9). What is fascia? What is its function?(10). Describe the relation of fasciæ to muscles(11). Describe the deep fascia. The superficial fascia. What is the function of each?(12). Describe the appearance of voluntary muscle. How may muscular fibres be obtained? Of what is each fibre composed?(13). What is the size of small muscular fibres?(14). What is the shape of a muscular fibre? Describe the structure of a muscular fibre, sarcolemma, membranes of Krause, muscular compartments, sarcous elements of Bowman, chief substance of Rollett, secondary substance(15-18). Describe the formation and appearance of a fibre(19). Describe the arrangement of muscular fibres to form anatomical muscles(20). What is the function of the connective tissue holding bundles of fibres together? Do the blood-vessels penetrate the sarcolemma? How are muscles nourished?(21). What prevents rupture of the smallest blood-vessels during muscular contraction? (22). Name the parts of a muscle. What is the origin of a muscle? the insertion? How do muscles begin? Where are they inserted? (23). How do muscles end in tendons? Are muscles the same structure throughout?(24). How are the fibres arranged in a long muscle? (25). Is there most tendon in connection with a muscle in youth or in old age? Name a muscle having a long tendon(26).

SECTION IV.

Describe an involuntary muscle-cell(1–4). What is the condition of a cell during contraction? How are cells held together? How long are they? Are they supplied with blood-vessels? What nerves stimulate them?(5). Where are they found? Describe the structure of the heart(6). How do involuntary muscles respond to a stimulus as compared with voluntary muscles?(7). Name some functions of muscles (8). How should muscles be used in order to keep them healthy?(9). How may muscles be made to increase in size? What kind of exercise is recommended to facilitate healthy muscular growth?(10). Of what importance is a knowledge of muscles to surgeons?(11). Name some benefits to be derived from muscular action(12). Tell what you know of the history of muscles(13).

CHAPTER VIII.

ANATOMY AND PHYSIOLOGY OF THE NERVOUS SYSTEM.

Nervous tissue is generally associated with muscular tissue; the presence of one indicates the existence and development of the other. Sensibility, like the power to move, secrete, excrete, and reproduce, is one of the fundamental functional properties of protoplasm; and as the very lowest forms of life, vegetable as well as animal, have the power to move without well-developed muscular tissue, so they have some peculiar and not well-understood inherent property which enables them to appear susceptible to various external influences. This property is called *sensibility*, and it exists independent of special nervous tissue. With the modification of protoplasm into muscular tissue, which is to be concerned in motion alone, comes the development of nervous tissue to receive impressions, generate nervous force, and convey stimuli or commands to the muscles; hence we should expect to find a well-developed nervous system only in those animals possessing a well-developed muscular system.

The nervous system is separate and distinct from all other systems of the body in its structure and in its

functions. It generates and conducts a peculiar force in obedience to the varied demands of animal existence. It resembles no other tissue in structure, and it imparts its mysterious power to no other organ or set of organs. Its important centres occupy the most protected situations in the body, and their branches are found ramifying in nearly every tissue of the economy. Innumerable armies of sentinels are developed in the cutaneous and mucous surfaces, imparting general sensibility to these structures as well as more deeply situated ones, especially commissioned to receive and appreciate some special quantity or quality of sensory impressions. Without the presence and directing power of nervous tissue no organ would be capable of properly discharging its function. It is the imperial master-tissue of the organism. All the others are subservient to it. For it all tissues were made. Muscles, bones, vessels, skin, mucous, serous, and synovial membranes, are obedient slaves, ready promptly to execute its every command.

SECTION I.

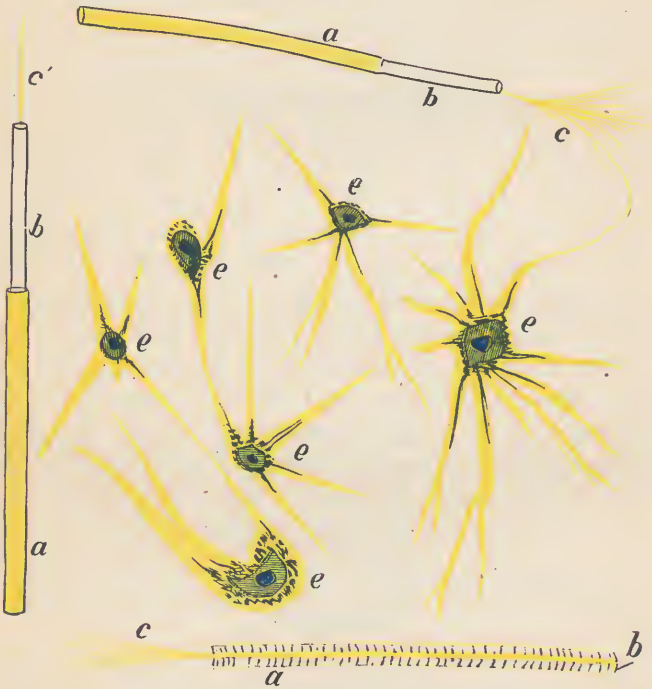
COMPOSITION AND DIVISION OF NERVOUS TISSUE.

1. Nervous tissue is composed of two distinct elements: *nerve-fibres* or *nerve-tubes*, and *nerve-cells*, *nerve-corpuscles*, or *nerve-vesicles*. A collection of nerve-vesicles constitutes a *nerve-ganglion*. A number of nerve-tubes or fibres bound together form a *nerve-cord*, or an ordinary anatomical nerve (Fig. 52).

2. Nervous tissue may be further divided, on ac-

count of its color, into *gray* and *white*. The white matter is composed of nerve-tubes or fibres. It is incapable of generating a nervous influence or stimulus, and acts merely as a conductor or medium of com-

Fig. 52.



NERVE-FIBRES AND NERVE-CELLS.

a, *a*, *a*, nerve-fibres; *b*, *b*, *b*, white substance of Schwann. The neurilemma is represented at *a*, *a*, *a*; *c′*, axis-cylinder; *c*, *c*, same breaking up into fibrillæ; *e*, *e*, *e*, *e*, nerve-cells, showing processes.

munication between the nerve-ganglia and the terminal nerve-endings. It is found in the nervous threads of

the cerebro-spinal system and in the white matter of the brain and spinal cord.

3. The **gray matter** is found on the surface of the brain (surrounding, as a layer of variable thickness, the white matter), and occupying the interior or central part of the spinal cord. It also occurs in the various ganglia, intermingled with the white or tubular matter, that occur at various points in the course of the cerebro-spinal nerves and in some of the nerves of special sense. This kind of nervous tissue is capable of generating a nervous stimulus or nerve-force, as well as acting as a conductor of nervous impulses.

4. Nervous tissues may again be divided into two great systems—the *cerebro-spinal* and the *sympathetic*. The **cerebro-spinal** system is composed of the brain (*cerebrum*, *cerebellum*, *pons Varolii*, and *medulla oblongata*) and spinal cord, with all the cranial and spinal nerves, as well as the ganglia developed in connection with them. This system is concerned with those functions of the body which characterize it as animal. It presides over voluntary as well as certain automatic movements. By it we become conscious of general sensibility and special sensations, and perform the various intellectual processes peculiar to higher animal life.

5. The **sympathetic** nervous system is composed of a number of ganglia arranged as a double row along the spinal column (one row on each side). These ganglia are connected by means of communicating fibres, called gray or gelatinous fibres, thus forming two chains of nervous matter. This system includes all the nerve-fibres which enter and emerge from the ganglia. It has no direct communication with the brain or spinal

cord, but communicates indirectly with these structures by anastomosing with the cranial and spinal nerves. This system presides over the so-called *vegetative* functions of animal life, and is especially concerned in the processes of nutrition. It stimulates to action the *involuntary* muscular tissue.

SECTION II.

NERVE-FIBRES.

1. There are several varieties of **nerve-fibres** found in the nervous system. Among these are those composed of the active part of the nerve alone; those which have a surrounding substance of a fatty nature insulating and protecting the active part; those having the active part and the insulating part both protected by a tubular sheath; and those with the tubular sheath surrounding the nuclei and the active part, the protecting fatty portion having disappeared (Fig. 52).

2. The **active** part of a nerve is called the *central axis-cylinder;* the insulating fatty matter surrounding this is called the *medullary sheath* or *white substance of Schwann;* and the tubular membrane which surrounds both of these is called the *neurilemma*, or Schwann's sheath. In addition to these structures, each axis-cylinder is surrounded by its own peculiar elastic sheath, composed of a substance called *neuro-keratin.* This sheath is supposed to lie between the axis-cylinder and the white substance of Schwann. **Nerve-corpuscles** are little bodies which lie between the neurilemma and the white substance of Schwann (Fig. 52).

3. **Medullated Nerve-Fibres.**—These are also called **complete** nerve-fibres, and are more complex than those hereafter to be described. They are made up of the central axis-cylinder and its sheath of neuro-keratin, the *myelin* or white substance of Schwann, and the tubular membrane called the neurilemma, with the nerve-corpuscles. Owing to the strong refractive power of the myelin or medulla, these nerve-tubes appear dark-bordered under the microscope. They are found constituting the great bulk of the cerebro-spinal nerves, a few only being found in connection with the sympathetic nerves. These fibres vary in their diameter from $\frac{1}{12000}$ to $\frac{1}{2000}$ of an inch.

4. The **axis-cylinder** is the essential part of every nerve. Without it no impulse can travel from nerve-centre to periphery or from periphery to nerve-centre. Upon its presence depends the functional and structural integrity of all nerves. It generally lies in the centre of the nerve-fibre, though it may be eccentrically situated. It varies in size with the size of the fibre which contains it, generally occupying from one-third to one-fifth of the diameter of the tube. In the natural state it is transparent and semifluid. After death, and especially after the application of certain reagents, it appears as a band made up of very delicate fibres (the elementary or primitive fibrils of Schultze), held together by a cement. At the termination of nerves in the skin and mucous membranes the axis-cylinder breaks up into these *primitive fibrillæ*, which form plexuses and end as terminal modifications concerned in the perception of general sensibility (Fig. 52). The elementary fibrillæ are also found in the dividing pro-

cesses of nerve-cells, in the terminations of the olfactory nerves, and in the nerve-layer of the retina. They are united into bundles by interstitial cement substance to form axis-cylinders.

5. **The White Substance of Schwann.**—This coat of medullated nerves is not concerned in conducting nervous impulses. It exists in what might be called the intermediate part of the nerve, being absent at its peripheral termination and central origin. It occupies all that part of the tube not occupied by the axis-cylinder and its sheath. It is composed of a homogeneous substance which is transparent, and in the recent state it is fluid in consistence. It is bright and glistening, and highly refractive like oil, and gives to the medullated fibres their dark borders and double contour. This substance surrounds the axis-cylinder as any insulating medium would surround and protect an electric wire.

6. Running from the *neuro-keratin* sheath of the axis-cylinder to the *neurilemma* are numerous very delicate fibres permeating the white substance of Schwann, and dividing the space between the axis-cylinder sheath and the neurilemma into a number of divisions. These divisions are filled with the medulla or white substance of Schwann, except a small area lying next to the neuro-keratin sheath, which is occupied by an albuminous fluid, and which seems to increase in quantity after contraction or shrinking of the axis-cylinder (Ewald and Kuhne) (Fig. 52).

7. Each nerve-fibre is bounded by the *sheath of Schwann*, which closely invests the white substance of Schwann, and which bears the same relation to the

nerve-fibre that the *sarcolemma* bears to the muscular fibre. This sheath is delicate, homogeneous, and slightly elastic, containing under it, here and there, elongated nucleated protoplasmic cells—the nerve-corpuscles. This tunic is found on all the medullated nerve-fibres irrespective of size, except those forming the white portions of the brain and spinal cord and the optic and auditory nerves.

8. **Remak's Fibres, non-medullated, sympathetic, pale, gray,** and **gelatinous,** are some of the names that have been given to those nerve-fibres which are destitute of the medulla or white substance of Schwann. They are composed of the axis-cylinder and its sheath, the neurilemma, and between these the nucleated nerve-corpuscles. Owing to the absence of the medulla, these fibres always show a longitudinal striation, due to the fibrillated structure of the axis-cylinder. They occur mostly in the sympathetic nervous system, though some are found in the cerebro-spinal nerves (olfactory nerves). All the nerves of the embryo are of this variety until the fifth month of intra-uterine life. The greater number of *invertebrate* animals have nerve-fibres of this kind. These fibres branch repeatedly and form plexuses, the large fibres dividing into smaller ones. They are pale in color or grayish, are always fibrillated, and have on their surface a number of elongated nuclei. They measure from $\frac{1}{900}$ to $\frac{1}{8000}$ of an inch in diameter.

9. **Incomplete Medullated Fibres.**—These fibres are made up of a central axis-cylinder, the neuro-keratin sheath, and the white substance of Schwann. The neurilemma is absent. Nerve-fibres of this variety are found in the white substance of the brain and its pro-

longation, the spinal cord, and in the optic and auditory nerves. The medulla in these nerves is laminated, and at various points in their course they present little nodular swellings called "varicosities," which give to the fibres an appearance something like a string of small beads. These protrusions are supposed to be due to an accumulation of a fluid albuminous matter between the neuro-keratin sheath and the white substance of Schwann.

10. At various distances apart in the complete medullated nerve-fibres there occur marked constrictions, as if a delicate thread had been tightly drawn around the nerve-fibre. These are called the *constrictions* or *nodes* of Ranvier, and that part of the nerve included between two constricted points is called the *internodal* segment. At the constricted points the medulla or white substance of Schwann is absent, and the neurilemma lies directly in contact with the sheath of the axis-cylinder. The constriction does not impinge upon the diameter of the axis-cylinder, and of course the conducting power of the fibre is unaltered. These fibres are considered by some authorities to be made up of a number of cells, the cells being the internodal segments with their nuclei. The nutritive materials from the blood probably gain access to the axis-cylinder by diffusing through the neurilemma and neuro-keratin sheath at the nodes. The fibres of Remak have no white substance of Schwann, and hence do not present the constrictions of Ranvier.

11. **Structure of an Anatomical Nerve-Trunk.**—Primitive nerve-fibrillæ are held together to form an axis-cylinder by a cement substance. The axis-cylin-

der is surrounded by a neuro-keratin sheath. Around this is placed a quantity of albuminous liquid, surrounding which is the white substance of Schwann, enclosed within the neurilemma. This constitutes a *nerve*-fibre. A number of nerve-fibres are held together by a very delicate connective tissue called the *endoneurium*, to form a *nerve*-bundle. Nerve-bundles vary in size according to the number of nerve-fibres they contain, and the size of the nerve-fibre depends upon the number of primitive fibrillæ entering into its formation.

12. Each **nerve-bundle** is surrounded by its own connective-tissue membrane. This membrane is called the *perineurium*. When a number of nerve-bundles are united by connective tissue common to all the perineurial sheaths, they form an ordinary anatomical *nerve-trunk*. The connective tissue which holds bundles together is called the *epineurium*. Nerve-trunks vary in size with the number of bundles they contain. **Nerve-sheaths** are supplied with their own nerves, which give to them sensibility. These are called the *nervi nervorum*, or nerves of the nerves.

SECTION III.

METHOD OF TERMINATION OF MOTOR AND SENSORY NERVES.

1. The brain and spinal cord are the most important nervous centres of the body. By means of the nerves they have direct telegraphic connection with the

skin, muscles, and viscera. All impressions of touch, sight, smell, taste, and hearing are telegraphed to the brain, where they become conscious sensations. The nerves that carry these impressions to the gray centres are called *afferent* or **sensory nerves.**

2. In obedience to the messages received, the nerve-centres generate motor influences which are conveyed to the muscles producing motion. Those nerves which transmit impulses from the centres to the muscles are called *efferent* or **motor nerves.**

3. All **sensory** impressions reported to the nerve-centres do not provoke corresponding motor impulses. The brain and spinal cord have the power to regulate and analyze these various impulses, and to answer only such as the requirements of the body or the will may demand.

4. **Motor** nerves are distributed to both voluntary or striated and involuntary or non-striated muscular tissue. Those motor nerves which end in voluntary muscles are derived from the cerebro-spinal nervous system, and those which end in involuntary muscles are derived from the sympathetic nervous system.

5. As medullated nerves approach muscular bundles they repeatedly divide, after entering the sheath of the muscles, until, generally, one nerve-fibre enters one muscular fibre. Before the medullated nerve-fibre enters the muscular fibre, the white substance of Schwann suddenly ceases, the neurilemma becomes blended with the sarcolemma of the muscular fibre, and the *axis-cylinder* is the only part of the nerve which enters the muscular tissue. Immediately after entering

the sarcolemma the axis-cylinder breaks up into primitive fibrillæ which form a swollen network imbedded in a mass of nuclei and granular matter immediately underneath the sarcolemma. This is called a *terminal nerve-plate* or an *end-plate.* Each nerve-fibre is supplied with one nerve end-plate, and sometimes, when the nerve-fibre is unusually long, there is an additional nerve-ending. Branches from the end-plate are probably continued on between the sarcous elements of Bowman.

6. As **non-medullated** nerve-fibres approach involuntary muscular tissue they divide, and then unite to form a plexus of axis-cylinders in the connective tissue of the muscle. Other fibres arise from this plexus to supply the bundles of muscle-cells, and these unite to form a more delicate plexus, which gives off primitive fibrillæ which run between the muscle-cells, and finally divide to be distributed to the nucleus or nucleolus of each cell (Arnold and Frankenhäuser). Muscles are also supplied with medullated nerve-fibres, which give them sensibility, though to a less degree than that of the mucous membranes and skin.

7. As **medullated** nerve-fibres approach their *peripheral termination* they lose the white substance of Schwann, after which they repeatedly divide and then lose their neurilemma. They now consist of the axis-cylinder alone, which divides into its primitive fibrillæ. These anastomose and form delicate networks which lie in the epithelial tissues of the hair-follicle, corneæ, skin, and mucous membranes. The terminal ends of these delicate fibrillæ lie in the tissue between the epithelial cells, in close contact with them, but do not enter their

substance. This is the method of termination of ordinary sensory nerves.

8. Besides these ordinary nerves of sensation, there are other peculiar modifications of sensory nerves for the perception of some special quality of nervous impressions. The most important of these are the Pacinian corpuscles or corpuscles of Vater, the corpuscles of Meissner or Wagner or tactile corpuscles, and the end-bulbs of Krause.

9. **The Corpuscles of Vater** surround the peripheral termination of medullary nerves in the subcutaneous tissue of the palms of the hands and soles of the feet. They also occur in connection with the nerves around joints, in the tunic of lymphatic glands, muscles of the hands and feet, the plexuses of the sympathetic in the abdomen, in the neighborhood of the coccygeal gland, near the abdominal aorta, on the external organs of generation of the male and female, near the pancreas and mammary gland, and on the nerves of the nipple.

10. They are oval or egg-shaped, measuring from one-twentieth to one-sixth of an inch in length and one-thirtieth to one-fortieth of an inch broad, and are composed of a number of laminæ or sheets of delicate connective tissue arranged about each other like the concentric layers of an onion. The number of capsules in each corpuscle varies from forty to sixty. The most external and internal layers are thin and close together, those intermediately placed being thicker and separated at a greater distance from each other.

11. These capsules are lined on the side facing the centre of the corpuscle by a layer of delicate endothelium. No fluid exists between the capsules (Hux-

ley), though some observers describe capillaries as ramifying between them (Todd and Bowman), and a fluid resembling lymph occupying the spaces between the most external layers.

12. Each **Pacinian corpuscle** contains within its centre an elongated clear space which is filled with a granular and nucleated substance, in which is imbedded the termination of the axis-cylinder of the nerve. Each corpuscle bears the same relation to a medullated nerve-fibre that a grape bears to its stem. As the nerve-fibre perforates the base of the corpuscle, it loses its investing tunics, which gradually become blended with those of the corpuscle, and when it reaches the central space the axis-cylinder alone remains. This enters the central bulb and lies imbedded in the granular matter, where it soon divides into two or more branches, each branch ending in a swollen, elongated, granular knob. The entire number of Pacinian corpuscles in the hands and feet is estimated at 2500. They occur in greatest numbers on the palmar surface of the fingers and the plantar surface of the toes, being especially numerous on the third phalanges. Nothing is definitely known of their special function.

13. The **Tactile corpuscles** or touch-cells lie in the papillæ of the skin. They exist in greatest number in the palms of the hands and soles of the feet, though they occur on the lips, tip of the tongue, nipples, back of the hands and feet, and anterior surface of the forearm. Like the corpuscles of Vater, they are most abundant in the fingers and toes. They are oval in shape, with a long diameter of $\frac{1}{300}$ of an inch, and they are $\frac{1}{500}$ of an inch broad. They are composed of a central part of

connective tissue harder than that of the Pacinian corpuscle, surrounded by a fibrous capsule containing elastic fibres. Each tactile corpuscle receives one medullated nerve-fibre, though sometimes more. Before entering the corpuscle the nerve makes one or two spiral turns around it, losing its external tunics. It then penetrates the capsule of the corpuscle, the axis-cylinder divides, the divisions unite with each other and run in a spiral course along the corpuscle, ending in swollen pale extremities which lie on the surface of the hard central core. These enlargements are called "touch-cells" (Merkel).

14. The tactile corpuscles are not found in all of the papillæ containing blood-vessels. By actual count of 400 papillæ containing blood-vessels, only 108 were found to contain tactile corpuscles (Meissner). They seem to occupy special papillæ which have no direct vascular supply (Kölliker).

15. Kohlmann has divided the hand into three tactile areas: the ball of the thumb and little finger, the tips of the fingers, and the three eminences at the lower part of the palm which lie in line with the intervals between the fingers, and which are well shown on forcible extension of the hand with the lateral surfaces of the digits touching each other. Of these areas, that containing the tips of the fingers is richest in the number of tactile corpuscles it contains, there being twenty-four in a length of two-fifths of an inch. In the eminences on the palm there are from two to five corpuscles, and on the thumb and little finger three to four in the same length.

16. The **end-bulbs of Krause** are much smaller

than the tactile corpuscles. They are composed of a capsule of connective tissue surrounding a soft homogeneous kernel. They are found in the mucous membrane of the nose, the conjunctiva covering the eye, the floor of the mouth, margins of the lips, glans penis, clitoris, mucous membrane of the rectum, and the circumvallate and fungiform papillæ of the tongue.

17. Generally, but one nerve-fibre enters the corpuscle of Krause, though two or three fibres may run to it. The surrounding sheath of the nerve-fibre becomes blended with the nucleated granular capsule of the corpuscle, and only the axis-cylinder enters the interior, which, after branching, ends in enlarged or knotted terminations near the distal extremity. The white substance of Schwann occasionally accompanies the axis-cylinder to near its termination in these corpuscles. They have a diameter of from $\frac{1}{1000}$ to $\frac{1}{250}$ of an inch.

SECTION IV.

NERVE-CELLS.

1. The nerve-centres contain, in addition to the cells of the gray matter, a very delicate supporting structure called the *neuroglia* of Virchow, some intercellular granular matter, lymphatics, and blood-vessels. In the brain the cells have no sheath, but those of the ganglia are surrounded by a capsule of connective tissue which is lined by delicate endothelial cells.

2. The **nerve-vesicles** or **ganglion-cells** are found in the brain and spinal cord, in the ganglia of the nerves that come from them, in some of the nerves of special

sense, and in the ganglia of the sympathetic nervous system. They are also found in those ganglia which

Fig. 53.



MULTIPOLAR BRANCHING NERVE-CELL, SHOWING THE NUCLEUS AND NUCLEOLUS.

a, axis-cylinder process, unbranched; *b*, *b*, branched protoplasmic processes (Landois). A mass of pigment-granules is seen near the entrance of the axis-cylinder process.

are mingled with the white or fibrous substance of nervous tissue (Figs. 52, 53).

3. Nerve-cells vary in size and shape in different divisions of the nervous system. In the spinal ganglia they are generally small, round or oval, with even borders. In the gray matter of the spinal cord they are larger in size (smaller in the posterior cornua than in the anterior), and irregular in shape, with numerous

branching processes. In the ganglia of the sympathetic they are irregular or angular in shape. In the cerebellum they are pear-shaped. In the cerebral convolutions they are ovoid, spherical, or pyramidal.

4. The cells of the gray matter also receive names according to the number of branches or processes they give off. When they present but one prolongation, they are called *unipolar cells.* If they have two branches, they are named *bipolar cells;* and to those having three or more processes the name *multipolar cells* is given (Fig. 53).

5. Large **multipolar cells** are found in the anterior horns of the spinal cord, in the cerebellum—where they have a different shape—in parts of the cerebrum, in the retina, and in the posterior horns of the spinal cord, where they are of small size and rarely have more than three processes.

6. **Bipolar cells** are found in the ganglia of the sensory roots of the spinal cord and the corresponding ganglia of the cranial nerves. These cells seem to be nucleated spindle-shaped enlargements of the axis-cylinder in the course of medullated nerve-fibres. Generally, the white substance abruptly terminates when it reaches the enlargement, though occasionally both this and the neurilemma are prolonged as a covering over the cells. These cells reach their greatest development in the fishes—pike and skate (Landois) (Fig. 52).

7. **Unipolar cells** exist in the ganglia of the spinal and cranial nerves, and in the ganglia of the sympathetic system.

8. The nerve-cells are composed of protoplasm which

is granular, and in which ramify a number of very delicate fibrils. The striated appearance, which is due to the fibrillæ, can be traced into the processes of the cell, where it appears, in some cases, to become continuous with the axis-cylinder of a medullated nerve-fibre. They are destitute of a capsule (except in the spinal ganglia), and contain a nucleus, which is large and provided with a surrounding membrane. They are of a reddish-gray color, and often contain pigment-granules, brown or yellow, scattered through the cell-contents or aggregated in distinct patches. Their diameters vary from $\frac{1}{300}$ to $\frac{1}{2500}$ of an inch, the nuclei in some cases being fully half the diameter of the cell (Fig. 53).

9. The method of the peripheral termination of sensory and motor nerves has been described, and it now remains to trace them to their central termination or origin, and study their method of attachment to the nerve-cells.

10. Besides the apparent and deep origin of the nerves from the nerve-centres, each constituent nerve-fibre of a nerve-bundle is probably attached to a ganglionic nerve-vesicle through the medium of one of its prolongations.

11. In tracing nerve-fibres from their peripheral termination in skin, muscle, glands, or mucous membrane to their central origin, we find they lose their neurilemma when they enter the white portion of the spinal cord and brain, and that the axis-cylinder is surrounded by its special sheath and the white substance of Schwann.

12. Medullated nerves of this variety, without a neurilemma, characterize the white substance of the

brain and spinal cord, the acoustic and the optic nerves; and as they enter the gray substance, central core of the spinal cord, and superficial strata of the brain, they lose the white substance of Schwann and ramify in the substance of the gray matter as axis-cylinders, or branches of these, to become continuous finally with the prolongations of the nerve-cells.

13. Multipolar cells have one process which does not branch. This is called the axis-cylinder process, because it has all the characters of the conducting part of a nerve, and has been traced and found continuous with this part of a nerve-fibre. After emerging from the nerve-cell it retains the characters of the axis-cylinder until it enters the white substance of the nerve-centres. Here it gains the white substance of Schwann, and as it leaves this portion of the centres it takes on the neurilemma, except the auditory and optic nerves (Fig. 53).

14. In addition to the large unbranched axis-cylinder process, multipolar cells have a number of smaller processes, which divide and subdivide repeatedly until they form networks of extreme delicacy. These processes are called *protoplasmic* processes, and those of one cell unite with those of adjoining cells, thus establishing a complete intercommunication between the nerve-corpuscles. Other of the *protoplasmic* processes unite to form axis-cylinders of medullated nerve-fibres. This is probably the mode of origin of the cerebral nerves, but it is not positively known that the cells of this region have an axis-cylinder process.

SECTION V.

THE BRAIN AND SPINAL CORD.

1. The **brain** and **spinal cord** are masses of nervous matter, situated within the cranial and spinal cavities,

Fig. 54.



VERTICAL SECTION OF THE BRAIN IN THE MEDIAN LINE.

1, corpus callosum ; 2, septum lucidum ; 3, cerebellum, showing the arbor vitæ ; 4, olfactory nerve ; 5, 5, 5, 5, surface showing convolutions.

composed of gray and white matter and surrounded by protecting and blood-supplying membranes (Fig. 54).

2. The brain is the nervous mass contained within the cranial cavity. It is divided into the *cerebrum* or **great brain**, the *cerebellum*, or **little brain**, the *pons Varolii*, and the *medulla oblongata*.

3. The **base** of the bony case containing the brain is perforated by a number of foramina and fissures for the exit of nerves and veins and for the entrance of blood-vessels to the brain substance. One of these, situated in the occipital bone, is of large size, is called the

foramen magnum, and transmits the tail-like prolongation of the brain—the spinal cord.

4. The **cerebrum** is the largest and most important division of the brain. It is composed of white matter with a cortex or covering of gray cellular matter, from one-twelfth to one-eighth of an inch in thickness. This cortical area of the cerebrum is the only part of the brain associated with the higher mental, intellectual, and moral faculties, such as consciousness, knowledge, volition, intellect, and will. This part of the brain is divided by a median longitudinal fissure into two hemispheres, *right* and *left*. The fissure does not extend entirely to the bottom, the two hemispheres being connected below by a bridge of white matter called the corpus callosum (Figs. 54, 55).

5. The **surface** of each hemisphere is uneven, presenting a number of folds, showing eminences and depressions resembling an extended accordeon bellows. These eminences are called *convolutions*, and the depressions are called *sulci* or *fissures*. The cerebral area, and hence the quantity of gray matter, vary with the number of convolutions and the depth of the sulci. The sulci generally have a depth of about 1 inch (Fig. 55).

Fig. 55.



SURFACE OF THE BRAIN, VIEWED FROM ABOVE.

Showing the fissure separating the two cerebral hemispheres and the arrangement of the convolutions.

6. Each **convolution** of the cerebral cortex is supplied with cells having a distinct individuality; hence different convolutions may be supposed to have different functions. The cortex is composed of a number of strata or lamina of cells superimposed one on another. These different layers are supplied with cells of the same shape and structure, but differing in size. Each cell communicates with cells of the same strata, and with those of the strata above and below, as well as with the axis-cylinder of cerebral nerves by means of its processes. On account of this arrangement the cells in different strata can act individually or combined.

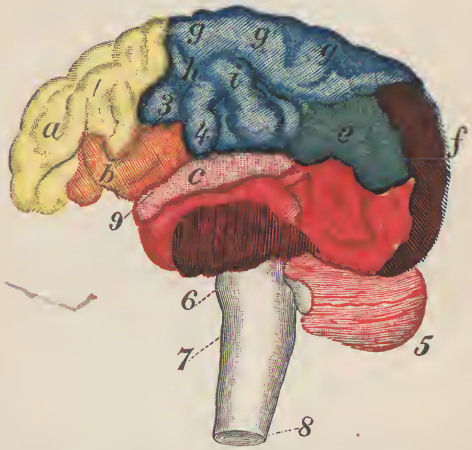
7. Each **cell** can receive impressions, generate a nervous force, and store up memories of past events. The cells in different areas of the cerebral cortex are believed to preside over special functions. There is an area for speech, areas for muscular movements, an area or centre for sight, one for taste and smell, one for hearing, one for the appreciation of pain, heat, cold, pressure, and touch, and one presiding over the higher mental faculties. Destruction or disease of any of these centres produces a loss or impairment of the corresponding functions. These areas are probably not distinct and separate, but gradually merge into each other, though some authorities claim that they are separated by distinct lines (Munk and Ferrier), while others contend that the brain can only act as a whole (Goltz and Flourens).

8. The important **lobes** of the cerebrum are the *frontal* and *parietal*, each having four convolutions; and the *temporal* and *occipital* lobes, each having but three convolutions. These lobes are separated from each

other by well-marked fissures, and are named from the bones near which they lie. The sense of sight resides in the occipital lobes, and if these be destroyed blindness results, though the structures of the eyes be unimpaired (Fig. 56).

9. The **temporal** lobes contain the conscious seat of hearing, taste, and smell. In disease of these lobes

Fig. 56.



BRAIN COLORED TO SHOW THE DIFFERENT CORTICAL AREAS.

a, seat of higher mental faculties; *b*, area of speech; *c*, area of hearing; *d*, area of taste and smell; *e*, area presiding over sensations of temperature, touch, and pain; *f*, area of sight; *g*, *g*, *g*, area for movements of the leg; *h*, area for arm; *i*, area for hand; 3, area for the face; 4, for the tongue; 5, cerebellum; 6, pons Varolii; 7, medulla oblongata; 8, spinal cord; 9, fissure of Sylvius.

the memory of sound is gone and deafness may result. Persons with this lobe diseased cannot give an intelligent answer to a spoken question, though when the same question is written for them they will comprehend it readily, because the structure of the *occipital*

lobes is normal. Imaginary odors have been reported to exist in disease of this lobe (Ranney) (Fig. 56).

10. The **frontal** lobe presides over the higher intellectual faculties, and in its inferior convolution partly resides the centre of speech. Disease of this area causes persons to use wrong words in endeavoring to express their ideas, and while they may perfectly understand all questions, sounds, and impressions, they cannot give a proper verbal answer, though able to write one with accuracy (Fig. 56).

11. The **parietal** lobes contain special centres of motion and tactile impressions. Professor Charcot reports the case of a gentleman who was unable to recognize either written or spoken language, but who easily comprehended the meaning of both by tracing out the forms of the letters. The habit of writing had caused the forms of letters to be associated with their corresponding ideas (Fig. 56).

12. The cerebral cortex is the seat of all conscious impressions. The cells in the different areas communicate with each other by fibres, whereby the impressions of one area can become associated with those of other areas. These fibres do not cross the mesial line, and they permit of a comparison of memories which are stored up in the different areas. Other fibres run between the corresponding areas of opposite sides of the brain, thus enabling the two sides to act together. Other fibres run to the skin, ear, nose, tongue, and eye, and still others to the spinal cord.

13. When the superficial part of the cerebrum is removed from an animal, it retains the power of voluntary movement, but only moves when excited by the

application of a stimulus, relapsing into an indifferent state when the exciting cause has been removed. It will swallow when water or food is introduced into the mouth, but it performs no voluntary conscious act. Sensibility remains, but the power of the perception of impressions is lost.

14. Situated in the white substance of the cerebrum are a number of gray masses. Two of these near the base are called the *optic thalamus* and *corpus striatum*. They are probably centres where all influences from the cord and cerebellum meet.

15. The **corpus striatum** has the power, with the aid of the cerebellum and without the influence of the cerebrum, to regulate the necessary complex movements executed in walking and standing erect. It also has the power to analyze messages from the cord, cerebrum, and cerebellum, and to respond by appropriate commands to impressions received when these do not require the special attention of the cerebral cortex. All of the so-called automatic or instinctive movements receive their stimuli from the cerebral or spinal ganglia, while the cerebral cortex is always concerned in originating those stimuli producing conscious movements.

16. The **optic thalami** are supposed by some authors to be concerned in the perception of smell, sight, hearing, and sensory impressions (Luys).

17. The **pons Varolii** is composed of transverse and longitudinal fibres intermingled with gray matter, being whiter externally than internally. It is a common point of meeting for the fibres from the crura cerebri, medulla oblongata, and cerebellum. It is a seat of

general sensibility, and probably acts with the cerebellum in muscular co-ordination when the cerebrum and ganglia at its base are removed. The longitudinal fibres are continuous below with the olivary and anterior pyramidal processes of the medulla oblongata—above with the crura cerebri. The transverse fibres unite the two lateral halves of the cerebrum. Some of its longitudinal fibres are continued below into the posterior and lateral columns of the spinal cord (Fig. 56).

18. The **crura cerebri** are rounded masses of longitudinal nerve-fibres, containing each a layer of gray matter (locus niger), which run from various parts of the cerebrum to the superior portion of the pons Varolii, where they become continuous with its longitudinal fibres. Each crus is a little less than an inch in length (Fig. 54).

19. The **cerebellum,** or **little brain,** is situated in the inferior fossæ of the occipital bone, being covered above by the posterior lobes of the cerebrum, from which it is separated by a process of the dura mater (tentorium cerebelli). Like the cerebrum, it is composed of a white interior covered with a layer of gray matter. The convolutions are more numerous and deeper and finer than in the cerebrum. In the centre of the white substance there is a gray mass called the *corpus dentatum.* In vertical section the gray matter of the cortex forms with the white substance a peculiar arborescent appearance called the *arbor vitæ* (tree of life) (Figs. 54, 56).

20. The cerebellum presides over the co-ordination of muscular movements, and when it is removed from animals they are unable to make proper co-ordination

of muscular movements, such as are required in maintaining the equilibrium, walking, feeding, etc., though the general and special sensibilities, involuntary motion, and intelligence remain. This part of the brain probably communicates with the muscular system through the posterior white columns of the spinal cord, as section of these produces similar results to those produced by extirpation of the cerebellum.

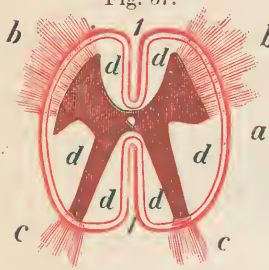
21. The **medulla oblongata** is a swollen mass of white and gray matter, extending from the pons Varolii to the upper border of the first cervical vertebra (atlas). It lies in a groove on the superior surface of the basilar process of the occipital bone, is one and a quarter inches long, three-quarters of an inch wide, and one-half an inch thick. It is continuous below with the spinal cord after passing through the foramen magnum, and is a centre for the origin of a number of important nerves. The centres of circulation and respiration are located here, and destruction or injury of this centre is followed by immediate death (Fig. 56).

22. The **spinal cord** is contained within the bony canal of the vertebral column. It extends from the upper border of the atlas to the lower part of the body of the first lumbar vertebra, where it terminates in a gray filament—the filum terminale. It is seventeen or eighteen inches long and weighs one and a half ounces. The *cauda equina* (horse's tail) is formed of the sacral and coccygeal nerves, which are given off from the lower part of the cord and emerge at the sacral foramina (Fig. 57).

23. The cord is composed of a central gray core, shaped something like the letter H, surrounded by white

fibrous matter. Thirty-one pairs of nerves arise from the spinal cord by two roots each, and emerge from the spinal canal by the intervertebral foramina, form plexuses, and supply mainly the extremities and trunk. The roots are called respectively the *anterior* and *posterior*. The latter has a ganglionic enlargement on it, while the former is smooth. The posterior is called the *sensory* root, and the anterior the *motor* root (Fig. 57).

Fig. 57.



TRANSVERSE SECTION OF THE SPINAL CORD, SHOWING GRAY AND WHITE MATTER.

a, pia mater; *b*, *b*, nerve-fibres from the anterior horns of gray matter; *c*, *c*, same from the posterior horns; *d*, *d*, *d*, *d*, white matter of the cord. The anterior and posterior fissures are seen at 1, 1; *e*, gray matter.

24. If the **posterior root** of a spinal nerve be divided, and the area supplied by that nerve be pinched or otherwise mutilated, the animal exhibits no evidence of pain, and will make no effort to withdraw the part, though perfectly able to do so when its attention is attracted through some other avenue (Fig. 57).

25. When the **anterior root** is divided and the animal subjected to the same treatment, it will evidence all the manifestations of suffering, without being able to withdraw the tortured part (Fig. 57).

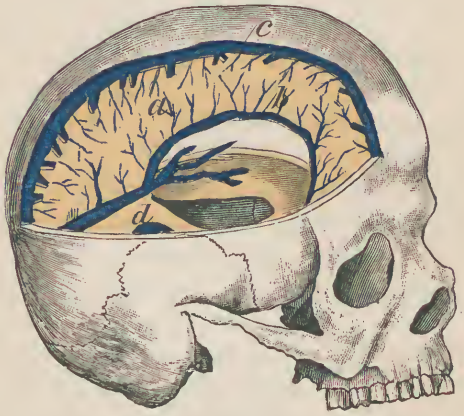
SECTION VI.

1. The brain and spinal cord are surrounded by three membranes, named, from without inward, *dura mater*, *arachnoid*, and *pia mater* (Figs. 57, 58).

2. The **dura mater** is the thick external covering of the brain, is intimately attached to the periosteum of the cranial cavity, and around the margins of the foramen magnum. It is not closely attached to the bony canal of the spinal column, except in front, but surrounds the cord as a loose sac.

3. In the brain it descends between the cerebral hemispheres, the cerebellar hemispheres, and between

Fig. 58.



REPRESENTS PART OF THE BONY WALL OF THE CRANIUM REMOVED TO SHOW THE FALX CEREBRI AND VENOUS SINUSES.

a, falx cerebri; *d*, tentorium cerebelli; *c*, sup. long. sinus; *b*, inf. long. sinus. The straight sinus connects the two.

the cerebellum and posterior lobes of the cerebrum. The process between the cerebral hemispheres is called the *falx cerebri;* that between the cerebellar hemispheres, the *falx cerebelli;* and that between the cerebrum and cerebellum, the *tentorium cerebelli* (Fig. 58).

4. The **arachnoid** is the delicate membrane, like a spider's web, between the dura mater and the pia mater. Between this and the dura mater is a space called the subdural space, while between the arachnoid and the pia mater is the subarachnoid space. Over the brain they are close together; in the cord they are slightly separated.

5. The **pia mater** is a delicate membrane carrying blood-vessels and nerves to the substance of the brain. It is the only membrane that follows the convolutions and dips into the sulci. The subarachnoid space communicates with the ventricles of the brain; the subdural space does not (Fig. 57).

6. There are a number of cavities within the brain called ventricles, and these communicate with each other. The subarachnoid space contains a fluid called the cerebro-spinal fluid. This communicates with that of the fourth ventricle through an opening (foramen of Magendie) in its roof. The quantity of fluid is normally about two ounces. It varies in the brain with the quantity of blood escaping into the spinal canal when this organ is congested. It acts mechanically in protecting the nervous mass, and forms a kind of "water-bed" on which the middle and posterior parts of the brain and the medulla rest.

7. The brain reaches its maximum weight at about forty years of age. Its average weight in the male, including the pons and medulla, is 50.21 ounces; in the female, 44.52 ounces (Reid). At birth the male brain weighs nearly 12 ounces, and the female brain, 10 ounces (Quain). According to the table of Reid, the cerebrum weighs 43.98 ounces, the cerebellum 5.25

ounces, the pons and medulla combined 0.98 ounce, in the male. The corresponding weights in the female are 38.75 ounces, 4.76 ounces, 1.01 ounce. These weights are a little high, according to many observers, the average weight of the male brain generally being given at 49½ ounces, and that of the female 44 ounces.

8. The elephant and whale are the only creatures possessing absolutely heavier brains than man, that of the elephant weighing 10 pounds and of the whale 5 pounds. The relative weight of the brain of man is greatest.

Below are the brain-weights of several distinguished men: Cuvier, 64.5 ounces; Abercrombie, 63 ounces; Ruloff, philologist, executed for murder, 59 ounces; James Fisk, Jr., 58 ounces; Daniel Webster, 53.50 ounces; Lord Campbell, 53.50 ounces; De Morgan, 52.75 ounces; Agassiz, 53.40 ounces; Gauss, 52.6 ounces; Dupuytren, 49.68 ounces. The brain of Cromwell is given by some authors at 82.29 ounces, and that of Byron at 79 ounces; these are thought to be unreliable.

9. The brains of idiots have been reported as low as 8½ ounces and as high as 48.67 ounces. Dr. James Morris reports the case of a bricklayer who could neither read nor write with a brain weighing 67 ounces. The case of a congenital imbecile is reported in the *West Riding Lunatic Asylum Reports*, London, 1876, p. 19, with a brain weighing 70.50 ounces. Generally, great mental power is associated with an enlarged brain-mass, though there are many exceptions to the rule. The brain diminishes in weight after forty years of age, losing about one ounce for each subsequent ten years.

QUESTIONS.

SECTION I.

Of how many elements is nervous tissue composed? What are they? What is a nerve-ganglion? How is an anatomical nerve formed?(1). Of what is white nervous matter composed? What is its function? Where is it found?(2). Where is gray nervous matter found? What are its properties?(3). What is the cerebro-spinal system? What is the function of this system?(4). Of what is the sympathetic nervous system composed? What is the function of this system?(5).

SECTION II.

How many kinds of nerve-fibres are there?(1). What is the active part of a nerve-fibre called? Name the structures surrounding it. What are nerve-corpuscles?(2). Describe a medullated nerve-fibre. Where are they found? What is their diameter?(3). Describe an axis-cylinder. What are primitive fibrillæ? Where are they found? How are they held together?(4). What is the white substance of Schwann? In what parts of the course of the nerve is it absent? What is its function?(5). What is the arrangement of structure between the neuro-keratin sheath and the neurilemma?(6). What is the sheath of Schwann? Where is it found?(7). Describe a fibre of Remak. What other names are sometimes given to them? Where are they found? What is their diameter?(8). Describe an incomplete medullated nerve-fibre. Where are they found?(9). What are the nodes of Ranvier? Where are they found? What is probably one of the functions of the nodes as regards the nutrition of the nerve?(10). Describe the formation of an anatomical nerve-trunk. What are the nervi nervorum?(11, 12).

SECTION III.

How do the brain and spinal cord communicate with the skin, muscles, etc.? Where are impressions of touch, hearing, sight, etc. made conscious? What are afferent or sensory nerves?(1). What are efferent or motor nerves? Does the brain and cord answer *all* impressions received?(3). To what kinds of muscular tissues are motor nerves supplied?(4). Describe the terminations of medullated nerve-fibres in muscular tissue(5). Describe the termination of non-medullated nerve-fibres in involuntary muscular tissue(6). Describe the method of ter-

mination of ordinary sensory nerves(7). Name some peculiar modifications of sensory nerves(8). Where are the corpuscles of Vater found? Describe them. How many are there in the hands and feet? What is their special function?(9–12). Describe a tactile corpuscle. Where are they found? What is their size? Describe the termination of nerves in them. Do they occur in all the papillæ? Name the tactile areas of the hand. Give the relative number of corpuscles in each area(13–15). Describe an end-bulb of Krause. Where are they found? How do nerves terminate in them? Does the white substance of Schwann ever accompany the axis-cylinder into the interior of the corpuscle? What is their diameter?(14–17).

SECTION IV.

Of what are the nerve-centres composed? What is peculiar about the nerve-cells of the brain?(1). Where are the nerve-vesicles found? (2). Describe some nerve-cells from the different divisions of the nervous centres(3). Do nerve-cells have any processes coming from them (4). Where are multipolar cells found?(5). Where are bipolar cells found? Describe a bipolar cell(6). Where are unipolar cells found? (7). Describe the structure and appearance of a nerve-cell. What is their diameter?(8). Describe the method of connection between nerve-fibres and nerve-cells. What is the axis-cylinder process of a nerve-cell? What are the protoplasmic processes?(9–14).

SECTION V.

Where are the brain and spinal cord situated? What surrounds them?(1). What are the main divisions of the brain called?(2). How do the nerves from the brain escape from the cavity of the cranium? What passes through the foramen magnum?(3). Describe the cerebrum. Where is its gray matter? How thick is the cortex? What is the function of the cortical area of the cerebrum? What is the corpus callosum?(4). Describe the convolutions and sulci. What regulates the quantity of gray matter? How deep are the sulci?(5). Tell what you know of the convolutions and their cells in the cortical area of the cerebrum. Name some special cortical areas(6, 7). Name the important lobes of the cerebrum and the number of convolutions each contain. Where is the sense of sight located?(8). What is the function of the temporal lobe? How can this be demonstrated?(9). What is the function of the frontal lobe? Where is the centre of speech?

Name some effects of disease of this area(10). What is the function of the parietal lobes? Is it possible for a person who can comprehend neither written nor spoken language to grasp its meaning by tracing the form of the letters with a pencil? Give an explanation of this(11). What is the function of the cerebral cortex? How do the cells in different areas and on opposite sides communicate with each other?(12). What is the effect of removal of the superficial part of the cerebrum? (13). What is the optic thalamus and corpus striatum? Where are they situated? What is their supposed function?(14–16). Describe the pons Varolii. Where is it located? What is its function?(17). What are the crura cerebri? Where are they located?(18). What is the cerebellum? What is its structure? its function? What is the arbor vitæ? What is the result of removal of the cerebellum from an animal? What separates it from the cerebrum?(19, 20). Where is the medulla oblongata? What is its structure? What is its size? What is its function? Can it be removed from an animal and the animal still live?(21). Where is the spinal cord? What is its structure? its size? What is the cauda equina? What is the filum terminale? How many spinal nerves are there? How many roots has each? What is peculiar about the posterior root? What is the function of each root?(22, 23). What is the effect produced by division of the posterior root?(24). What is the effect of division of the anterior root? What would be the effect of dividing both roots?(25).

SECTION VI.

Name the membranes surrounding the brain and spinal cord(1). Describe the dura mater. What is the falx cerebri? the falx cerebelli? the tentorium cerebelli?(2, 3). Describe the arachnoid. Where is the subdural space? the subarachnoid space?(4). Describe the pia mater. What is its function? Does the subdural space communicate with the ventricles of the brain?(5). What is the cerebro-spinal fluid? What is its quantity in health? What is its function?(6). When does the brain reach its maximum weight? What is its weight in the male? in the female? What does it weigh at birth? What animals have absolutely heavier brains than man? How much does the brain diminish in weight after forty years of age?

CHAPTER IX.

THE ACTION OF ALCOHOL AND NARCOTICS ON THE NERVOUS SYSTEM.

SECTION I.

1. **Prolonged** use of alcoholic beverages produces a diseased condition of nearly every tissue and organ of the body. It leads to congestion, inflammation, and ulceration of the mucous membrane lining the alimentary canal, and is most marked in its effects on the lining membrane of the stomach, causing a diseased condition of the glands which manufacture the gastric juice, and resulting in stomach weakness and the various forms of *indigestion* and *dyspepsia.*

2. It causes enlargement of the liver by inducing an excessive growth of useless connective tissue, which presses upon the active parts of this organ—the liver-cells—or steals their food from the blood; or the connective tissue may contract, press on the liver-cells and the ducts leading from them, and thus reduce the organ to the condition of a small, hard, nodular lump. It may also lead to a fatty degeneration of the anatomical elements of the liver, interfering with the formation of healthy bile, without which life cannot exist. Fat occurs in abnormal quantities in the blood, the

coats of the blood-vessels become diseased, the kidneys become inflamed, the heart-muscles undergo a change into fat, and the lungs become congested, interfering with the purification of the blood.

3. As marked as are the effects of alcohol on the structures named, still more dangerous are the effects of this thief of human happiness and life on the nervous system.

4. The membranes of the brain and cord become thickened and inflamed, the brain-cells become shrivelled and unable to act, the intercellular nervous matter is increased and watery, the blood-vessels rupture and cause hemorrhage within the brain-substance, large quantities of fluid are found in the cavities and subarachnoid space, and the whole brain becomes contracted, small, and firm, or soggy and œdematous.

5. The imagination is unusually active, the emotions are stimulated, and the judgment is destroyed. The sensory terminations of the nerves are blunted; the cerebellum loses its power of muscular co-ordination; the staggering gait, with many absurd and ridiculous movements, is produced; the cerebrum becomes influenced; all sense of decency and order is lost; and the victim, bereft of morals, intellect, sensibilities, and will, is reduced to a condition lower than that of the brute.

6. The drinking of large quantities of alcohol by those unaccustomed to its use, to soothe mental troubles and drown sorrow, produces a species of delirium called *mania à potu*. Preceding the stage of complete exhaustion is one of violent delirium and great mental excitement, during which the appetite is lost, the mind re-

fuses to rest in sleep, and the victim becomes suspicious of friends and attendants. When sufficient spirits have been taken to produce profound intoxication, the unfortunate one lies in an insensible condition. Voluntary power over the muscles is lost; the eyes are swollen and congested; the pupil may be regular and respond to light or it may be dilated; the pulse is at first rapid, then slow and weak; the face is bloated and red; the lips puffed and purplish; and the breathing slow and puffing.

7. **Delirium Tremens** is the name of a condition produced by acute alcoholic poisoning in those accustomed to its excessive use, and in which advanced diseased conditions of the various organs of the body exist. It is characterized by trembling of the muscles of the extremities, body, and tongue. After a prolonged "spree" the nervous symptoms become more pronounced, the stomach is weak and unable to hold food, vomiting occurs, and sleep becomes impossible. The sufferer imagines friends, articles of furniture, the decorations of the bed-clothing, walls and carpets of his apartments, to be transformed into frightful monsters, demons, lizards, goblins, and snakes, which menace his safety and constantly seek his destruction. He is filled with horror and fright; the illusions and hallucinations become constant; he critically and timidly examines every corner and closet of his room, makes constant efforts to elude his pursuers, and engages in terrible conflicts with his imaginary enemies. Illusions and delusions of feeling, smell, and hearing occur in addition to those of sight. He hears strange and terrible noises, perceives disagreeable odors, experiences the

feeling as of insects crawling over his body, and fights frantically with those who come near him, until, from sheer physical exhaustion, he sinks into a condition of depression. He has to be guarded and restrained to prevent injury to himself and friends. Large doses of alcohol have caused sudden death in those unaccustomed to its use, a case being reported where one ounce of whiskey caused death in a child.

8. Loss of sensibility (*anæsthesia*), convulsions, paralysis, mental derangement, suicide, and murder are some of the results produced by its use.

9. **Opium** is derived from the unripe capsules of the poppy (*Papaver somniferum*). The plant is cultivated to some extent in the United States, but more extensively in Asia Minor, Persia, India, Turkey, and Europe. Asia Minor furnishes the largest quantity of opium to America. The habit of smoking and chewing opium is popular in the Eastern countries, especially in Turkey and China, and even in more advanced nations it is not unknown.

10. Opium is the great reliever of pain, but it speedily destroys the nervous system and enslaves its victim. It produces a quieting effect on the nerves; induces a dreamy condition, accompanied with a feeling of perfect satisfaction; ideas pass rapidly before the mind; the intellect seems exalted, the imagination is stimulated, and true mental power is diminished.

11. Care should be exercised in the use of opium for the relief of pain, as the habit is readily acquired, and when the system has once experienced its effects, the appetite for the poison is increased with each gratification of the desire. Those addicted to its use will

use any means, however dangerous and humiliating, to procure the drug.

12. When constantly used, the eyes become glassy and the expression vacant, the pupils contracted, the countenance sallow and pinched, and the moral and mental faculties blunted.

13. It occurs in laudanum, paregoric, and the various soothing syrups for infants and children. It contains a number of alkaloids, of which the most important and most frequently used are morphia and codeia. One-sixth of a grain of morphia has produced death in an adult; it produces death by acting directly on the centres of respiration. Children are very susceptible to the poisonous effects of opium in any form.

14. **Tobacco** is a native American plant. It was introduced into England by Sir Walter Raleigh. The leaves are chewed and smoked; it is also used in the form of snuff and cigarettes. When habitually used, in excessive quantities, it produces gastric pain, indigestion, muscular trembling, shortness of breath, impaired memory, and irregularity of the heart's action. The effects of its immoderate use by those unaccustomed to it are very dangerous. It causes intense sickness, followed by vomiting, great depression, cold and clammy skin, ending in convulsions and death.

15. Its active principle is *nicotia*, one drop of which will kill a rabbit (Taylor). It is employed in medicine to produce emesis (vomiting), to relax spasm, and in the form of poultices to relieve inflammations and painful swellings. Its internal administration is always dangerous, many cases of death having resulted even from its medicinal use. The habit of smoking cigar-

ettes and blowing the smoke through the nostrils is exceedingly dangerous, as the *nicotia* is strained out by the mucous membrane of the soft palate and nasal cavities, and is absorbed into the blood. Smoking alone has caused death. The smoke of one-half an ounce of tobacco contains sufficient poison to prove fatal (Melsens).

16. **Chloral hydrate** is used in medicine as an anodyne and hypnotic. In small doses it acts directly on the cerebrum and induces sleep. The pupils are contracted, and when large doses have been taken the temperature of the body is diminished. It causes paralysis by acting on the spinal cord; the circulation becomes weaker, and the action of the heart sluggish and feeble. The respiration is at first slow and deep, but it soon becomes rapid, shallow, and irregular. In those suffering from the "chloral habit" there are irregularities and disturbances of the respiratory function, eruptions of the skin, congestion of the mucous membranes, small subcutaneous hemorrhages, and the formation of ulcers.

17. Within the body chloral probably breaks up into chloroform and formic acid. It produces death by paralysis of the nervous centres, influencing first the respiration and then the heart. Ten grains have been known to cause death in an adult.

18. **Cocaine** (or *cucaine*) is the active alkaloid of the plant *Erythroxylon coca*. It was probably first obtained by Gaedeke in 1855, under the name of *erythroxylene*. Its benumbing effects have been known since its discovery, but it was not generally employed as a local anæsthetic until Koller of Vienna demonstrated its efficacy to prevent pain during operations on the eye,

in September, 1884. The first operation performed with its aid in the United States was by Dr. Bull of New York, in October of the same year. Though generally employed in minor eye surgery (in the form of a 4 per cent. solution of the hydrochlorate of cocaine), it has been successfully used in operations of as great magnitude as amputation of the thigh. A few cases of the "cocaine habit" have been reported, in which the effects of the drug have been characterized by loss of mental power, by moral depravity, and by insanity. Death has resulted from its use, and less than one-half a grain has caused dangerous symptoms.

19. **Coffee** is used in the form of a decoction of the roasted berry of the plant (*Caffea Arabica*) as a common beverage by nearly all nations of the earth. It contains about one-third to 1.736 per cent. of an active alkaloid (*caffein*) and an empyreumatic oil, upon which its stimulating properties depend. When strong coffee is taken in quantity, its effect upon the nervous system is very pronounced. It appears to produce increased brain-power, stimulating the reasoning faculties as well as the imagination. It acts directly upon the cerebrum, causing persistent wakefulness, and will stir a tired brain to increased activity. Through the spinal cord it produces nervous and muscular restlessness. When poisonous doses of the alkaloid caffein are given to an animal, the heart is at first active in its pulsations, which later become slow and irregular, and finally cease. Coffee diminishes the elimination of the waste products of the tissues (especially urea), and acts as a muscular as well as a nervous stimulant.

20. **Tea**, as a beverage, is used probably by more

persons than coffee, considering the dense populations of China and Japan. Its alkaloid is *thein* (identical with caffein), of which it contains sometimes as much as 6.21 per cent. (Peligot). It is generally employed in the form of an infusion of the dried leaves of the tea-plant (*Thea Chinensis*). It acts upon the system like coffee, though its effects are not so pronounced, quickens the circulation, stimulates the action of the skin, and lessens the action of the bowels. Its action on the kidneys is not so great as that produced by coffee. In certain parts of the north of China the inhabitants use tea to deodorize and purify the water, which during the winter season becomes offensive from the presence of large quantities of animal matter. By using it as tea they escape all its bad effects (Friedel). A similar habit is practised by the Tartars with their "brick tea" to render potable the water of the steppes. There are many kinds of tea in use. The principal varieties of green tea are Twankay, Gunpowder, Caper, Hyson, and Hyson-stem. The chief black teas are Bohea, Pekoe, Souchong, Oolong, and Congou. Green tea is more powerful as a stimulant than black tea (which contains but one-half as much ethereal oil ($\frac{1}{2}$ per cent.) as green tea). Black tea is poorer also in thein and tannin, and not so detrimental to digestion as green tea. Both kinds are subject to adulteration, green tea being colored or "faced" with Prussian blue, indigo, the salts of copper, and other poisons, while black lead is employed to give "bloom" to black teas (Letheby).

21. **Sleep** is a demand by the tissues of the body for rest. Muscular fatigue may be relieved, to some extent, during the waking moments, but so imperative is the

demand on the part of the nervous system for rest that locomotive engineers have been known to sleep while running at a high rate of speed after the red flag of danger had been waved full in their faces, and instances are given where soldiers have slept while executing forced marches, and even during the heat of battle.

22. Early childhood and youth require more sleep than adult life and old age. Its approach is heralded by a feeling of drowsiness and general physical and mental apathy; the avenues of communication with the external world are all closed; the windows through which the mind examines nature are darkened; general sensibility is diminished; and one by one the special senses are lulled to silence. Consciousness is lost when sleep is profound. The potential energy of the nervous system has been expended; it must be restored during sleep.

23. It frequently happens, when the brain is shut off from all communication with the external world, that all the cortical centres are not influenced by sleep at the same time. The intellectual and other areas may work with varying degrees of activity and consciousness while separated from any external stimuli, producing hallucinations and the various forms of dreams. That the processes of reasoning and thought may take place during sleep seems probable from the reports of cases where mathematical problems of great length and intricacy have been solved, where artists have given the master-touches to their productions, and where literary compositions of great merit have been produced during this condition.

24. During sleep the brain contains less blood than

during the waking moments. Congestion of the brain causes *coma*, not sleep. Sleep is probably more a cause than a result of the diminished amount of blood in the vessels of the brain. The average amount of sleep required is given at eight hours in every twenty-four. Children while growing require much more than adults, and brain-workers need more than other laborers.

QUESTIONS.

SECTION I.

What is the effect of the prolonged use of alcohol on the tissues of the body? How does it affect the alimentary canal? What effect does it produce on the lining membrane of the stomach? How does it favor indigestion and dyspepsia?(1). How does it affect the liver? How does it influence the quantity of bile? What is its effect on the blood? the heart? the kidneys?(2). How does it affect the nervous system? (3). How does it affect the membranes of the brain? the brain-cells? the blood-vessels of the brain? the fluid of the brain-cavities? What does it do to the brain-tissue?(4). How does it act on the imagination? emotion? judgment? How does it influence the sensory nerves? the cerebellum? What kind of a gait does it produce? To what condition does it bring its victim?(5). Describe *mania à potu*. What causes this affection? Describe the state of complete intoxication(6). What is delirium tremens? How is it produced? Describe the symptoms produced by this affection. Have large doses of alcohol caused death? How much whiskey has killed a child?(7). Name some of the results produced by the use of alcohol(8). From what plant is opium obtained? In what countries is it cultivated? What country furnishes America with most of her opium? In what countries is the habit of chewing and smoking opium most prevalent?(9). What is the effect of opium when given to those suffering with pain? Describe some symptoms produced by its use(10). Should it be administered with care in cases of sickness? Why?(11). What effect does it produce when habitually used?(12). In what forms does it occur? What are

its principal alkaloids? How does morphia produce death? What is the effect of opium on children?(13). To what country is tobacco indigenous? By whom was it introduced into England? In what forms is it used? What are some of the dangerous effects produced by its use?(14). What is its active principle called? How much will kill a rabbit? For what is it employed in medicine? Is it a dangerous remedy to use? Is the practice of smoking cigarettes a dangerous one? Why? Has smoking ever caused death? How much poison is in the smoke of one-half an ounce of tobacco?(15). For what is chloral used? Name some effects produced by the use of this drug. What becomes of it within the body? How does it produce death? How much has caused death in an adult?(16, 17). What is cocaine? By whom was it first obtained? When? In what form? When was it first employed in surgery? By whom? Who first used it in surgery in the United States? When? For what is it principally used? In what form? What effects does it produce when used for any length of time? Has death ever been caused by its use?(18). In what form is coffee used? From what plant is it obtained? Upon what does its stimulating properties depend? Describe the effect of strong coffee on the nervous system. How does it influence the cerebrum? What effect has it on the elimination of the waste products of the body? What are the effects of poisonous doses of caffein?(19). Describe the action of tea as a beverage. For what is it used by the Chinese and Tartars? Name some varieties of green tea; of black tea. Which is the best tea to use—green or black? Why? Are teas ever adulterated with poisonous substances? For what purpose?(20). Describe the phenomena of sleep. How much sleep is needed in the twenty-four hours? Do children or adults need most? What is the condition of the vessels of the brain during sleep? Does the brain ever act during sleep? What are dreams?

CHAPTER X.

STRUCTURE AND FUNCTION OF THE ALIMENTARY CANAL.

SECTION I.

1. **Permanency** of structure is incompatible with activity and life in all forms of organic nature. When the protoplasm of low forms of animal and plant life is deprived of a portion of its water or otherwise subjected to unusual conditions, it may remain for a time with its structure unchanged until the return of favorable conditions (moisture, temperature, pressure, darkness, light, etc.), when its dormant life becomes aroused and shows itself in activity and change.

2. With every action of animal life some of its structure is changed, some of its substance is consumed, every act is accompanied with tissue-change; some living active matter is transformed into dead, worthless, and poisonous ash. In order to live and work, all parts of the body must not only be cleansed and purified of their effete matter, which is the result of tissue-work, but this must be replaced by new materials. The tissues derive their nourishment from the blood, which would soon become impoverished were it not regenerated from some source.

3. The alimentary canal and lungs are the main

sources of supply to the blood (the lungs favoring the introduction of oxygen into the blood), and as the digestive tract will hold but a limited quantity of food at any one time, its contents soon become consumed, and fresh food and drink must be introduced from the external world. Life and death go hand in hand: tissue-work causes tissue-death, and tissue-death makes life possible.

4. With every act a want is created, and when this want becomes sufficient it creates the sensations known as hunger and thirst.

5. **Hunger** is a cry of the tissues for solid food.

6. **Thirst** is a want of the tissues for pure water.

7. When the promptings of hunger and thirst are not obeyed by the introduction of food and drink, the demand on the part of the tissues becomes most imperative; intense suffering is experienced, and as the tissues are consumed and poisoned by their worn-out matter, violent delirium supervenes, leading oftentimes to cannibalism, murder, and death.

8. The most immediate demand of the tissues is for air, after which follow, in order, the demands for water and for solid food. The time during which life could exist without food or drink must vary with age, sex, condition of development, health, temperature, etc. Death is said to occur after total deprivation of food in from five to eight days. Of one hundred and fifty persons who were exposed to the sea on a raft for thirteen days as a result of the wreck of the frigate Medusa in 1816, only fifteen persons survived. The young and the aged will succumb to starvation more readily than the adult in the prime of life.

9. The sensations known as appetite and hunger are referred to the stomach, but it is a mistake to believe that this is the only part that needs replenishing. It needs an increased supply only in so far as it forms a part of the general economy. If the nutritive matters be properly prepared and introduced into the circulating fluid, either by direct injection into the blood-current or by absorption by the mucous membrane of some other division of the alimentary tract, the indications are fulfilled, and a feeling of satisfaction is substituted for the one of hunger.

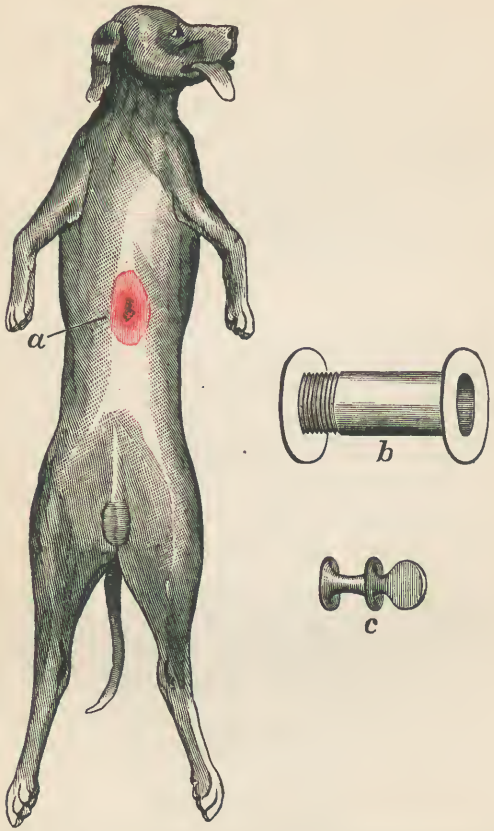
10. In like manner, the sense of thirst is generally referred to the mouth and upper part of the throat, and that of impending suffocation to the respiratory passages and lungs. The want really exists in the tissues, and is probably felt by the stomach, mouth, throat, and air-passages, because these are the avenues through which food, water, and air are introduced into the system.

11. That the sense of thirst is not located in the parts named may be demonstrated by making an opening in the stomach of an animal (dog) which will communicate with the external world through an opening in the walls of the abdomen, into which is fitted a tube provided with a cork or stopper. When the stopper is removed and the animal is allowed to drink, the water passes out through the opening in the stomach nearly as fast as it enters from the œsophagus, and, notwithstanding the fact that the water is constantly bathing the mucous membrane of the mouth, throat, and œsophagus, the sense of thirst does not seem to be relieved, and the animal will continue to drink. When

the stopper is introduced, he will drink the usual amount of water necessary for a thirsty dog, and quits with seeming satisfaction. The explanation is simple: As long as the water was discharged from the stomach, the want indicated by thirst remained. When the opening was closed, the water was absorbed by the vessels of the mucous membrane, gained access to the blood-current, visited the tissues, and satisfied their craving, when the sensation of thirst disappeared.

12. The operation is a simple one and rarely proves fatal, the animal apparently enjoying as good health after the experiment as before. The opening is called a gastric fistula, and the operation was probably first done by Bassow in 1842, though cases of gastric fistula in the human being as the result of injury had been observed many years before. A very interesting case, and one generally fully described in works on human physiology, is that of a Canadian by the name of Alexis St. Martin, who sustained, as the result of a gunshot wound, a fistulous opening in the left side of the stomach nearly three inches in circumference. The wound was partly covered by a flap of mucous membrane which could easily be displaced with the finger, and thus permit the escape of gastric juice or the various products of gastric digestion. This case was made the subject of numerous observations by Dr. Beaumont, who studied the phenomena of digestion and the action of the gastric juice. This accident occurred in 1822, and observations on the case were reported as late as 1856. During these years St. Martin enjoyed good health and performed hard labor. Fig. 59 represents a

Fig. 59.



Dog showing gastric fistula at *a*; *b*, silver tube used in the operation; *c*, key of the same. The tube in this case, having been removed after two years, established an opening between the stomach and external world, through which material from that organ is constantly discharged during gastric digestion, enough being absorbed, however, to meet the demands of nutrition.

dog with a gastric fistula, now in vigorous health more than three years after the operation.

SECTION II.

1. The alimentary canal in the higher animals is the great supply-station of the body. Its function is to prepare food-materials for absorption.

2. In the lowest forms of life any part of the animal has the power to act as a digestive organ; the protoplasmic mass simply surrounds the food and absorbs it. As the complexity of the animal increases, the surface becomes depressed. This depression acts as a food-sac or stomach for the animal in which it occurs. It gradually deepens until, in some animals (*Hydra*), it is likened to the space between the walls of a bag or sac, the same opening answering for mouth and vent. In others (*Anthozoa*) it is likened to a double sac, or like a bottle with the neck turned in. The sea-urchin has an alimentary canal passing through the body, with both mouth and vent, the effete matter not being discharged from the opening through which it entered.

3. The alimentary canal of the clam is peculiar in that its stomach lies in the liver, and the intestine passes through the heart. Between the highest and lowest animals the alimentary canal presents great variations in structure, length, and development. In fishes and amphibians (*frogs*) the canal is generally short. Those animals not provided with teeth to masticate their food (*insects, birds*) have an excessive muscular development of some part of their alimentary tract for the purpose of triturating or grinding their food, with the aid of small gravel or grains of sand, after it has been swallowed (gizzard of the common fowl). In birds of prey the gizzard is much more

poorly developed than in those that feed on hard cereals.

4. In carnivorous animals (*flesh-eaters*) the alimentary canal is generally short. In herbivores (*vegetable-feeders*) it is very long and complex, attaining a length of one hundred and fifty feet in the full-grown ox. In man, who is an omnivorous animal, it measures but from five to six times the length of the body. Herbivorous animals are compelled to take a great mass of food for a given amount of nutriment, while the food of the carnivores is in a more condensed form; hence the difference in length of the alimentary canals.

5. The alimentary canal in man is divided into the mouth, pharynx or throat, œsophagus or gullet, stomach, small intestine (divided into three parts, duodenum, jejunum, and ileum), large intestine (divided into the ascending, transverse, and descending colon), sigmoid flexure, and rectum. Near the junction of the ileum with the ascending colon is an appendage (the vermiform appendix) which is generally attached to the round beginning of the colon (*cæcum*, or *caput coli*, as it is called). Nearly all parts of this canal exercise some function in the process of digestion (Fig. 60).

6. A short description of the various *divisions* of the alimentary canal, with the fluids which are poured into them, will be followed by a general *classification* of foods, and the action, so far as known, of the different digestive fluids on each.

7. The **digestive tract** is lined with mucous membrane, which is covered with various forms of epithelium in different parts. It contains many small

Fig. 60.

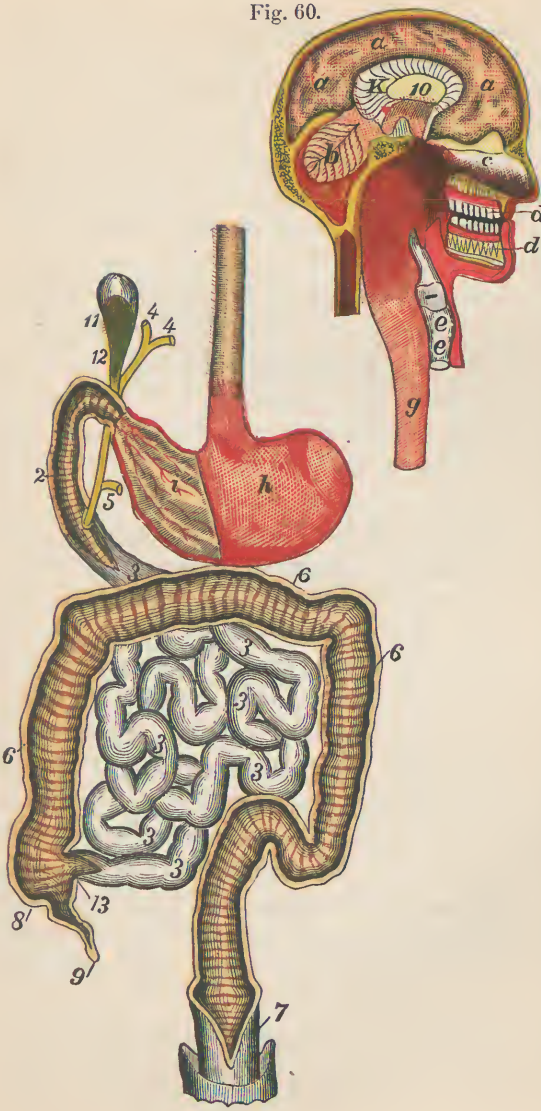


Fig. 60.—*a*, *a*, *a*, cerebrum; *k*, corpus callosum; 10, septum lucidum; *b*, cerebellum showing the arbor vitæ; *c*, filaments of the olfactory nerve to the nose; *d*, *d*, teeth, showing bone cut away to expose the roots; *e*, *e*, trachea; *g*, œsophagus; *h*, muscular tissue of the stomach; *i*, its mucous membrane; 11, gall-bladder; 4, 4, hepatic ducts; 12, cystic duct; 5, pancreatic duct; 3, 3, 3, small intestine; 2, inner surface of the same showing the valvulæ conniventes; 6, 6, large intestine; 7, rectum; 8, cæcum; 9, vermiform appendix; 13, ileo-cæcal valve.

glands imbedded in its substance, and is perforated by the ducts of glands which pour their secretion into its lumen. The mucous membrane is described as a modified skin, the alimentary canal being likened to the finger of a glove invaginated or turned outside in. The covering of the margin of the lips gradually merges into skin on the outside and mucous membrane on the inside.

8. The act of seizing food to convey it to the entrance of the alimentary canal is called *prehension* (to seize, to lay hold), and the members of the body used for the purpose are called the organs of prehension. In animals that graze, for example, the lips, teeth, and tongue are the organs used, while in man these are aided by the hands.

9. The **mouth** is the first division of the digestive tract. In the higher animals (mammals) it is furnished with teeth, which vary in number from one in the narwhal to two hundred and twenty in the dolphin.

10. It is absolutely necessary that the food be in a condition of solution before it can be absorbed into the system, and it is well known that the more finely a substance is divided the greater surface does it expose to a solvent and the more easily it becomes dissolved. The function of the teeth is to cut, tear, and grind the food. When the action of the teeth has been sufficient, the action of the solvents of the body is effected with ease. Rapid eating produces indigestion and dyspepsia. Good teeth and thorough mastication are essential to good health.

11. The number of permanent teeth in man is thirty-two, sixteen in each jaw. The number of tem-

porary, deciduous, or milk teeth is twenty. The teeth are divided into those of the upper and those of the lower jaw, and according to their function have received different names, as *incisors*, *canines*, *premolars*, and *molars*. Each tooth is composed of *a crown*, *a neck*, and *a root* or *fang* (Fig. 61).

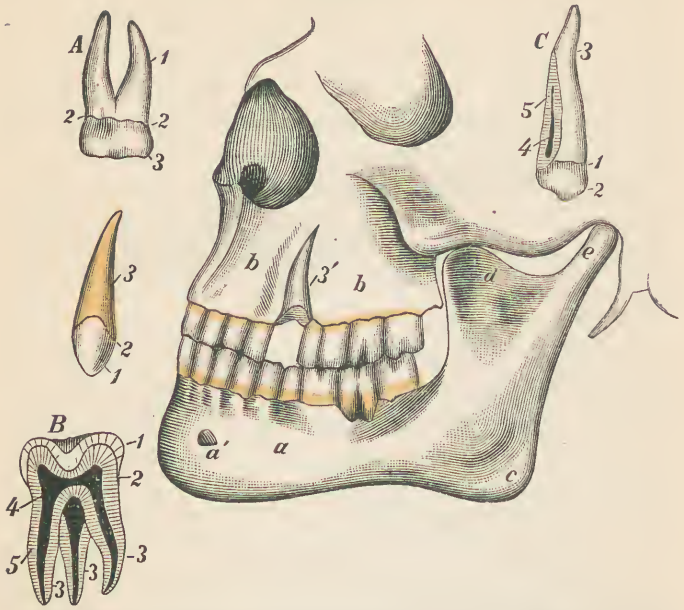
12. The **crown** is the body of the tooth which projects beyond the gum; the **root** is the part which is lodged in the jaw-bone; the **neck** is the narrow constricted part between the crown and the root or fang.

13. The crown varies in shape in the different teeth. It is covered with enamel, which is the hardest substance in the body, containing scarcely 2 per cent. of animal matter. It is thickest on the most exposed part of the crown, where it often exists in several layers. As the crown tapers toward the root, the enamel becomes thinner and terminates at the neck.

14. The **fang** or root is covered with a thin layer of cement, *crusta petrosa* (hard crust), which is true bone. It is thickest at the apex of the root, gradually becoming thinner as it approaches the neck, which it covers, and becomes blended with the enamel of the crown. Covering the enamel is a very delicate skin, about $\frac{1}{30000}$ of an inch in thickness, called the cuticle of the teeth or Nasmyth's membrane. It is of animal composition, and its function is to protect the enamel from the action of acids. The enamel covering the teeth of man is not renewed when once destroyed, while in the rodents (gnawing animals) it is reproduced when worn away (Fig. 61).

15. The mass of the tooth, which is covered by the enamel and cement, is composed of a substance called

Fig. 61.



DESIGNED TO SHOW THE RELATION OF THE TEETH TO THE JAW-BONES.

a, inferior maxillary bone; *b*, *b*, superior maxillary bone; *a′*, mental foramen; *c*, angle of the jaw; *d*, coronoid process; *e*, condyloid process; 1, 2, 3, shows the crown, neck, and root or fang of the canine tooth; 3′, shows the excavation in the upper jaw for the reception of its root; the anterior wall has been cut away. The white part of the teeth represents the crown; the colored portion shows the roots running into the bone, which has been partly cut away at a lower molar tooth.

A, lower molar: 1, fang; 2, neck; 3, crown.

B, upper molar tooth: 1, crown; 2, neck; 3, 3, 3, fangs; 4, pulp-cavity; 5, dentine.

C, canine tooth: 1, neck; 2, crown; 3, fang; 4, pulp-cavity; 5, dentine.

dentine or *ivory*, as it occurs in the elephant's tusk. It differs from true bone in that it has no lacunæ and canaliculi. In its centre, running from the cement at

the apex of the root to the enamel of the crown, is a cavity containing the small nerves and blood-vessels of the tooth. This is called the pulp-cavity, and is the only sensitive part of the tooth (Fig. 61).

16. The **permanent incisors** number four in each jaw. They are the flat teeth situated in the front of the jaws, are sharp-edged for cutting, and have each a single root. The incisors of the upper jaw are larger than those of the lower, and the central ones are larger than the lateral ones. The elephant has no incisors in the lower jaw; the ox and sheep none in the upper; the squirrel has two in each jaw, the rabbit four above and two below; the lion has six in each jaw.

17. The **canines** number two for each jaw. They resemble somewhat the tearing teeth of the dog, hence the name canine. They are more conical than the incisors, next to which they are placed, and have but one root, which is very long and deeply placed in the corresponding alveolar depression of the jaw. The superior canines are sometimes called the eye teeth, and the inferior ones the stomach teeth (Fig. 61).

18. Next to the canines, going backward, are the **premolars** or **bicuspids**, called *premolars* because they are in front of the molars, and *bicuspids* because they have two cusps. They number four in each jaw. The crown presents two tubercles, the external one being slightly the longer. The upper bicuspidati are slightly larger than the lower. The roots of the lower bicuspidati are invariably single, while the first bicuspidatus of the upper jaw commonly has two roots, an external and an internal root. The second generally has a single root, which is grooved to indicate a division.

If the tongue be passed over the inner surface of the canine teeth, each upper one will present a small tubercle near the gum, indicating a bifurcation of the crown, while the inferior ones will be found to be smooth. The length of the roots of the bicuspids are about equal with those of the incisors.

19. The **permanent molars** are six in number in each jaw. They are called the first, second, and third molars, and are situated just back of the bicuspids. Their crowns present a rounded surface with eminences and depressions to make a kind of millstone for grinding. The grinding surfaces are broad, and have as many as four or five cusps or tubercles. The first molar is the largest; then the second; the third, called the *dens sapientia* (wisdom tooth), is the smallest. They generally have three roots in the upper jaw and two in the lower. Sometimes the roots above number four or five instead of three, or they may all be united into one irregular root, as is common with the wisdom teeth (Fig. 61).

20. The permanent incisors appear at about the seventh or eighth year, the canines at eleven or twelve years of age, the bicuspidati at from nine to eleven, the first molar at from the sixth to the seventh year, the second molars between twelve and thirteen years of age, and the wisdom teeth appear between the eighteenth and twenty-fifth years of life; sometimes they never cut the gum.

21. The teeth, with the aid of the powerful muscles of mastication (*temporal*, *masseter*, *pterygoids*), grind the food into a pulpy mass, the cheeks, lips, and tongue keeping it between the cutting and grinding surfaces,

and rolling it from side to side, thoroughly mixing it with the fluids of the mouth.

22. This constitutes the acts of mastication and insalivation (mingling with the saliva). The food is then passed back by the tongue to the posterior part of the mouth, where it is surrounded by the soft palate, tongue, and pillars of the fauces, and forced into the pharynx, where it is grasped by the action of the muscles of this part, which contract from above downward and send the bolus of food into the œsophagus, which is a muscular tube about nine inches in length lined with mucous membrane arranged in longitudinal folds, leading from the lower part of the pharynx or throat into the stomach. When the food reaches the upper opening of the œsophagus or gullet, the muscles of this tube, which are arranged in two layers mainly (circular and longitudinal), contract from above downward and rapidly strip it into the stomach. The action of the muscular fibres of the œsophagus is admirably shown in a horse while the animal is drinking (Fig 61, *g*; Fig. 62, 2).

23. The **pharynx** is separated from the mouth in front by the soft palate. It is attached to the occipital bone (basilar process) above, and completed behind by the union of the muscles of which it is formed. It is pyramidal or funnel-shaped, with the large end upward. Its greatest diameter is opposite the great horn of the tongue-bone, and it is smallest where it leads into the gullet. Its length is about four to five inches.

24. It has opening into it the mouth in front, œsophagus below, posterior nares above, Eustachian

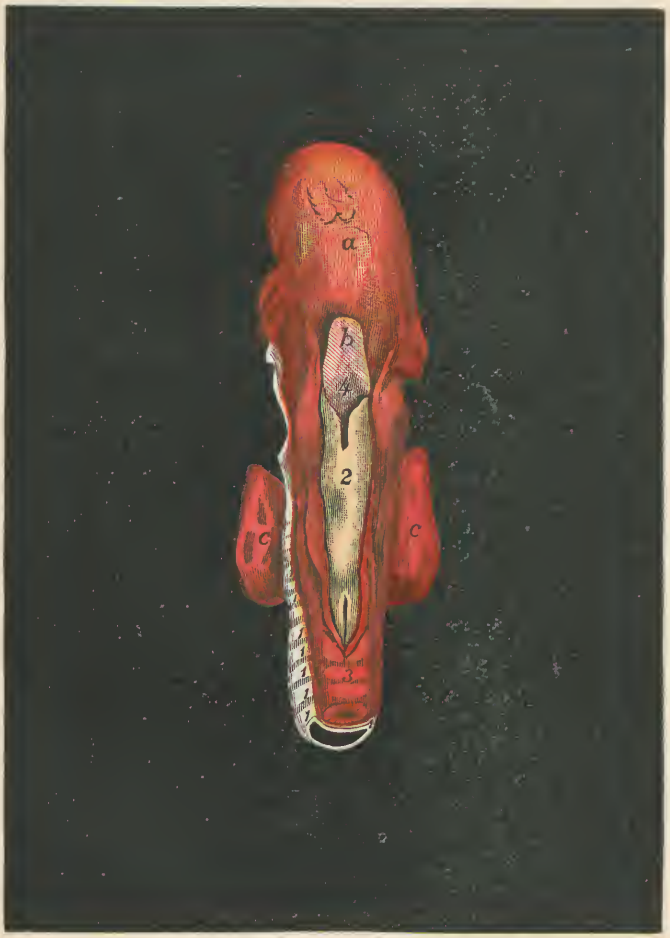


FIG. 62.—TONGUE, ŒSOPHAGUS, EPIGLOTTIS, AND TRACHEA, POSTERIOR VIEW.

a, tongue; *b*, epiglottis; *c*, *c*, thyroid gland; 1, 1, 1, 1, 1, 1, rings of the trachea; 3, œsophagus or gullet; 2, inner surface of the same; 4, opening into the trachea or windpipe, which is closed over by the epiglottis during deglutition.

tubes leading to the middle ear, and the opening leading into the larynx and trachea (windpipe).

25. During deglutition (swallowing) the food is prevented from going into the posterior nares by the soft palate, and into the opening into the larynx by the epiglottis, which covers over the opening with each act of deglutition (Fig. 62, *b*).

26. The **stomach** is the largest expanded portion of the alimentary canal, serving as a receptacle for food, and containing in its walls numerous glands which secrete fluids that are important in digestion. It is a simple muscular bag in those animals that live on flesh, but in those that subsist on a complex diet it is more complicated, being often divided by constrictions into two or more compartments. The crocodile has a muscular stomach resembling the gizzard of birds. The stomachs of crabs and lobsters have teeth. The stomach of the horse is divided by a constriction into two parts. In rodents and porpoises the constrictions are well marked. Even in man, during the act of digestion the stomach is divided into a greater and lesser pouch by the oblique muscular fibres. The most complicated stomachs are found in the ruminants (animals that chew the cud). In these it consists of four divisions. The first division is called the *rumen* or *paunch*. It is the largest division, and receives the food from the œsophagus. In the camel tribe it contains large reservoir cells for storing up water. The next division is called the honeycomb stomach or *reticulum*. This division receives water when it is first swallowed: it is sometimes called the water-bag. It also receives the food from the rumen, makes it into little balls, and sends it back to

the mouth for more thorough mastication. These two parts are considered to be modifications of the lower part of the œsophagus. The third division is called the strainer, or *psalterium*. Its mucous membrane is arranged in folds which are so placed as to present the appearance of a harp with its strings. It is also called the manyplies. It is the smallest division, receives the food from the œsophagus after the second mastication, and sends it to the fourth division, which is the true stomach, called the *abomasus*. Here it meets the true gastric juice.

27. In the human subject the œsophagus expands into the stomach immediately after passing through the diaphragm. As it passes through this partition it is surrounded by muscular fibres which during contraction of the diaphragm constrict the lumen of this tube, preventing regurgitation of the contents of the stomach. Hence the great effort required to effect emesis at the end of the inspiratory act, when the diaphragm is in a condition of contraction (Fig. 63, 8).

28. The stomach is suspended from the œsophagus, by which, with the aid of folds of the peritoneum, it is held in position. It is situated in the upper part of the abdominal cavity, under the diaphragm and liver, and above the transverse division of the large intestine, in what are called the left hypochondriac and epigastric regions. Its form is described as being conical, or shaped like a powder-horn, placed transversely in the abdominal cavity, with the large end to the left and the small end to the right side. The large end is called the fundus or cardiac end; the small end is called the pyloric or intestinal end. The curves are known as the

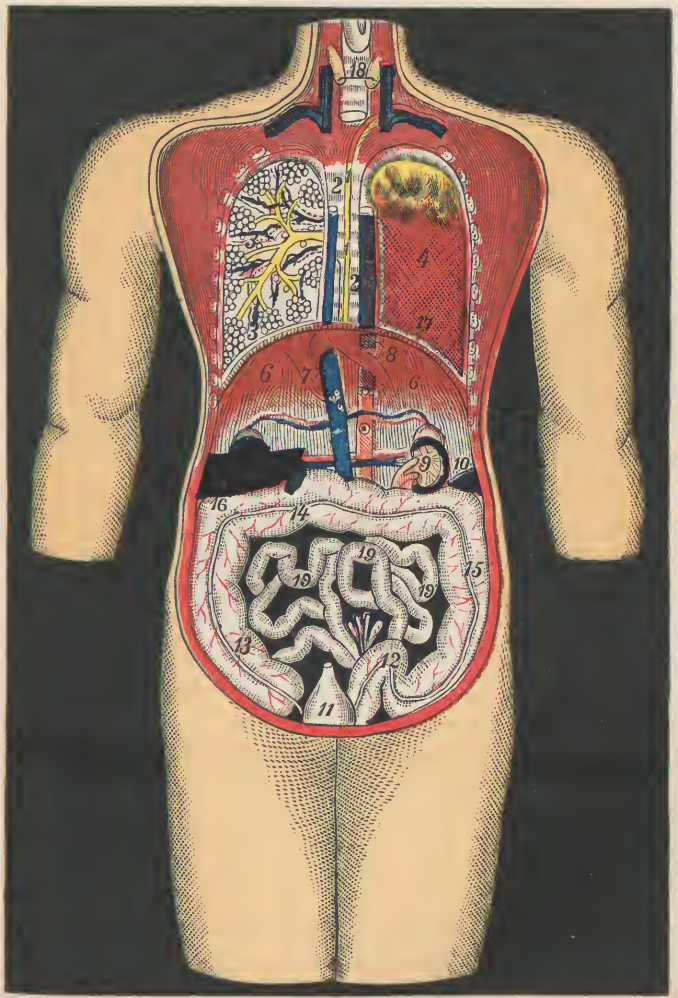


FIG. 63.—1, 1, thoracic duct; 2, 2, vertebral column; 3, 3, lung-cells; 4, solidified lung in pneumonia, above which is a phthisical cavity; 5, aorta; 6, 6, diaphragm; 7, ascending vena cava; 8, œsophagus; 9, kidney; 10, part of spleen; 11, bladder; 12, sigmoid flexure; 13, ascending, 14, transverse, 15, descending colon; 16, liver; 17, pleura; 18, thyroid gland; 19, 19, 19, small intestine.

superior or lesser curvature (Fig. 65, 6), with its concavity looking up, and the inferior or greater curvature, with its convexity looking down (Fig. 65, 5). The opening into the œsophagus is called the cardiac opening (Fig. 65, 4), that into the intestine (duodenum), the pyloric opening (Fig. 65, 8). It weighs about four and a half to seven and a half ounces, is twelve to fifteen inches long, four to five inches in its vertical diameter, and holds about five pints.

29. The stomach has three coats—an external peritoneal coat, about $\frac{1}{300}$ to $\frac{1}{175}$ of an inch thick; a middle muscular coat, from $\frac{1}{50}$ to $\frac{1}{25}$ of an inch thick, arranged in three layers—the external longitudinal layer, most distinct on the upper curvature; the inner circular layer, most distinct to the right of the cardiac end and at the pyloris, where it forms a thickened muscular ring at its junction with the small intestine; the oblique layer, not so well developed, is internal to the circular layer, and is confined to the fundus, which it covers in an oblique manner from left to right; above, it is limited to the left of the entrance of the œsophagus; below, to the left one-third of the greater curvature. Contraction of this layer produces the two divisions of the stomach during digestion. These muscles are of the involuntary variety, and are supplied with numerous blood-vessels (Fig. 60, *h*) and an internal mucous coat.

30. The mucous membrane is the internal coat. It is arranged in folds in the long axis of the stomach, and is loosely attached to the submucous coat. It is soft and velvety, of a pink or reddish-brown color, covered with epithelial cells, is from $\frac{1}{75}$ to $\frac{1}{25}$ of an inch

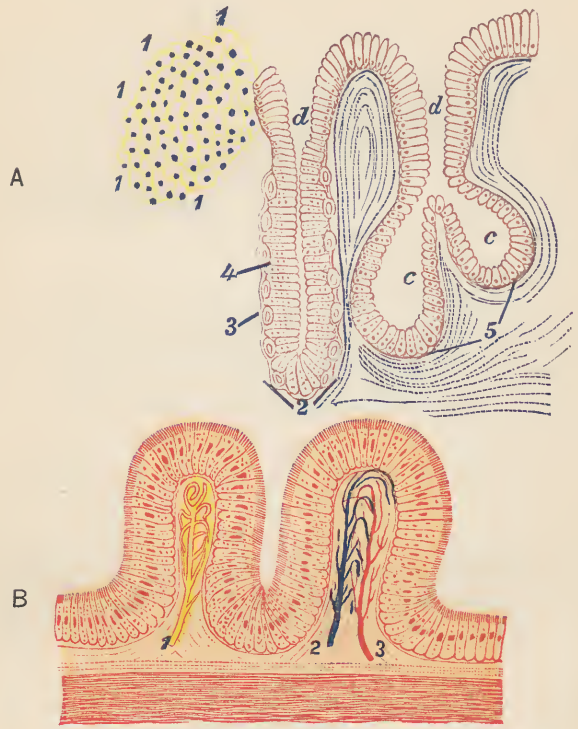
thick, and is perforated by a number of little openings which lead into the gastric follicles (Fig. 60, *i*; Fig. 65, 7, 7, 7).

31. These little openings are situated at the bottom of little pits which cover the mucous membrane and give it the appearance of honeycomb. Each pit is from five to six sided, and is $\frac{1}{100}$ to $\frac{1}{200}$ of an inch in diameter (Fig. 64, 1, 1, 1). This is the appearance of the reticulum, and the folded arrangement of the mucous membrane gives the appearance of the psalterium or strainer in the ruminants.

32. These little openings lead into the glands of the stomach, which are situated underneath the mucous membrane in the submucous tissue, which is richly supplied with blood-vessels, and is sometimes called the vascular coat.

33. There are two main varieties of glands in the stomach, called *peptic* and *acid* glands (Fig. 64, *A*, 2, 5). The **peptic glands** are composed of several short tubes which open into a common duct, which appears as a little opening at the bottom of one of the little depressions. The duct is about the same length as the tubes leading to it. These glands are lined by epithelial cells, which are cubical or cuboidal in shape and granular (during digestion). Their duct is lined with columnar epithelium like that covering the mucous membrane of the stomach, with which it is continuous. These glands occur in greatest numbers in the pyloric end of the stomach, and to some extent around the œsophageal opening. They secrete pepsin or a material which is easily converted into pepsin, called by a variety of names—propepsin, pepsinogen,

Fig. 64.



A.—1, 1, 1, 1, pits showing openings as dark spots of the glands of the stomach; 2, an acid gland; 3, an acid cell; 4, peptic cell; 5, a peptic gland, lined with peptic cells; *c*, *c*, *c*, *c*, the secreting part of the glands; *d*, *d*, the excretory portion.

B.—Two intestinal villi, showing the nucleated and striated epithelium, with a lacteal at 1, a vein at 2, and an artery at 3, much magnified.

zymogen. These are the pyloric glands of some writers.

34. The **acid glands** occur in greatest numbers in the cardiac end of the stomach, though they are scattered throughout its inner surface, except near the pylorus, where they are supposed to be absent. In structure they resemble the peptic glands, differing, however, in the length of the excretory duct, which is much shorter, being only one-fifth to one-sixth the length of the tubular gland, and in the character of the lining epithelium, which, in addition to the cuboidal variety found in the peptic glands, have short columnar cells at the neck where the tubular glands open into the duct, and large spheroidal or round, dark, granular cells situated between the peptic cells and the basement membrane, upon which they rest. These are the *acid cells*, sometimes called parietal cells. They are the peptic cells of some writers.

35. The acid glands secrete pepsin with the aid of their peptic cells, while they secrete an acid (free hydrochloric) with the aid of their acid or parietal cells. The substance formed by the peptic cells is probably changed into pepsin by the acid formed. Pepsin is forming during the intervals of digestion. Acid is formed during digestion, when the previously formed pepsin is washed out. These are the peptic glands of some writers (Fig. 64).

SECTION III.

1. Following the stomach is the **small intestine**, from twenty to twenty-three feet long, and divided into three parts: the *duodenum*, named because it is about

as long as twelve fingers are wide; the *jejunum* (empty), named because it is generally found empty after death: this forms the upper two-fifths of the small intestine not formed by the duodenum; the *ileum* (to twist), so named on account of its coiled condition, forms the remaining three-fifths of the small intestine. The small intestine has a peritoneal coat, which does not completely cover the duodenum, and a muscular coat of two layers—external longitudinal and internal circular. These are of involuntary muscular structure, and produce the movements of the intestines (Figs. 60, 63).

2. The **mucous membrane** is arranged in folds which run transversely around one-third or one-half of the lumen of the tube, and, unlike the folds in the gullet and stomach, are not obliterated during distension of the bowel. They begin at from two to three inches from the pylorus, and are lost at the lower third of the ileum. They are more numerous above than below. They number about 850 (Sappey). By this arrangement the mucous membrane presents more than double the surface that would otherwise be presented. These folds are called the *valvulæ conniventes*. They increase the surface exposed to the food, and probably retard to some extent its onward movement (Fig. 60, 2).

3. Thickly placed all over the mucous membrane of the small intestine, and covering the valvulæ conniventes, are a number of small mucous-membrane elevations, most numerous in the duodenum and jejunum, called the *intestinal villi*. They are covered with striated cylindrical epithelium, the markings being confined to the ends of the cells (Fig. 64, *B*), and contain blood-vessels, probably sympathetic nerves, lacteals, and

muscular cells continuous with those of the intestine. They are concerned in absorption. They are $\frac{1}{20}$ to $\frac{1}{30}$ of an inch long and $\frac{1}{50}$ to $\frac{1}{140}$ of an inch wide at their base. They number throughout the small intestine from four to ten millions (Fig. 64, *B*).

4. In addition to these structures, the small intestine contains a number of glands—*solitary glands, patches of Peyer*, which are inflamed in typhoid fever, the *glands of Brunner*, and the *follicles of Lieberkuhn*. The patches of Peyer are more numerous in the lower part of the ileum, the glands of Brunner, in the upper one-half of the duodenum, and the follicles of Lieberkuhn are found throughout the mucous membrane of the small intestine. They are tubular glands, opening between the villi and furnishing the most important part of the intestinal juice. The small intestine also receives the pancreatic juice from the pancreas and the bile from the liver by a common opening for the ducts of these two glands in the lower part of the descending portion of the duodenum.

5. The **large intestine** serves mainly as a reservoir for the refuse portion of the food. Its divisions have already been given.

6. The composition of animals and plants differs mainly in the relative amount of carbon and nitrogen found in each. Plants are composed chiefly of non-nitrogenous (ternary) compounds, carbon being considered the important element. Animals are composed mainly of nitrogenous compounds (quaternary), which, in addition to carbon, hydrogen, and oxygen, contain nitrogen, which is here considered the chief element.

7. Both kinds of compounds are, however, found in

either branch of life, and it is believed that no substance is found exclusively in the one or in the other. Among the substances found in the vegetable kingdom that contain nitrogen may be mentioned gluten, vegetable protoplasm, casein, albumen, and fibrin. Cholesterine, which is largely separated from the blood of animals by the liver as an excrementitious substance mainly formed in the nervous tissues, is found in the leguminous plants. Among the substances found in animal tissues that were thought to be peculiar to plants are cellulose, which is a substance related chemically to starch, occurring as the wall of vegetable protoplasmic cells (found in the mouth of Ascidians), and chlorophyll, which is the green coloring-matter found in the leaves of plants, with the aid of which their protoplasm is enabled to form starch from carbonic-acid gas and water in the presence of sunlight (found in *Hydra*, *Stentor*, *Bonellia*).

8. Those plants that find their food already prepared for them have no chlorophyll. They are called parasitic plants (saprophytic when living on decomposing organic matter), among which may be mentioned the broom-rape (*Orobanche*), which grows on the roots of many wild plants; one variety (*O. minor*) may be found on clover, and another (*O. ramosa*) on tobacco and hemp; the yeast-plant (*Torula cerevisiæ* and *Saccharomycetes ellipsoideus*), which causes the fermentation of wort and must in the manufacture of beer and wine; the various forms of disease, ferment, and color-producing micro-organisms (*Bacteriaceæ*); the fungi or moulds occurring on old boots, shoes, preserves, jams, and stale bread, and those microscopic forms producing diseases of cultivated crops, as

the rusts and mildews of grasses, wheat, oats, barley, and corn (*Puccinia graminis*), the potato fungus (*Peronospora infestans*), and the American grape mildew (*P. viticola*); the smut of barley, oats, wheat, and rye (*Ustilago carbo* or *U. segetum*), that of Indian corn (*U. maydis*), and millet (*U. destruens*), and the bunt or stinking smut of wheat (*Tilletia caries*, *T. fœtens*, and *T. tritici*).

9. The manifestation of animal life depends upon the power of animal protoplasm to elaborate food-materials into its own substance, manufacturing complex and unstable compounds, which contain large quantities of latent or potential energy from the food-matters in the blood, and the analysis or decomposition of these highly unstable compounds into those that are less complex and more stable, converting energy of position into energy or power of motion (*kinetic energy*). These changes occur in the presence of oxygen, and the processes of animal life are said to be changes due to oxidation and analysis, while those occurring in vegetable life are due to deoxidation and synthesis (building up), the kinetic energy (*motion*) of heat and light being changed into potential energy (*position*), and the simple and rather stable compounds, water (H_2O) and carbon dioxide (CO_2), being converted into more complex and less stable compounds, starch ($C_{12}H_{20}O_{10}$). There are other changes (oxidation), occurring in chlorophyll-bearing plants in darkness, in which the starch is converted into food-matters for the plant—cane-sugar ($C_{12}H_{22}O_{11}$), grape-sugar ($C_{12}H_{24}O_{12}$), etc. The protoplasm of vegetable life is formed by these substances, and others chemically related, with the aid of the nitrates and sulphates absorbed by the roots from the soil.

SECTION IV.

CLASSIFICATION OF ALIMENTARY PRINCIPLES.

1. All the foods of the body may be classified as follows: *Organic nitrogenized, organic non-nitrogenized, inorganic.*

2. The **organic nitrogenized** principles are probably the most important, if importance can be given to any one class. They are derived from both the animal and vegetable kingdoms. They exist in one form in the external world, undergo a change before they are absorbed from the alimentary canal, are changed in their chemical nature again before or as they are worked into animal tissue, and undergo yet another change when they have subserved their function and are discharged from the body as worn-out material. They are indefinite in chemical composition. They never exist in the body unless intimately combined with inorganic matter, and they are discharged in health, though in a different form from that in which they entered.

3. Some of the substances of this class derived from the animal kingdom are found in lean meat, eggs, and milk. They are—musculin or myosin, albumen, casein, gelatin, fibrin. Those derived from the vegetable kingdom are—gluten, found in wheat and other cereals; vegetable albumen, and vegetable casein, which is derived from peas and is made into a cheese by the Chinese. It is also found in other leguminous plants, and is supposed to be analogous to animal casein derived from milk, as it exists in the cheese of commerce.

4. The **organic non-nitrogenized** principles are derived from both the animal and vegetable kingdoms.

They are represented by the sugars, starches, fats, and the various mucilages and gums found in plants.

5. **Sugar** is derived from both animals and plants. Animal sugar occurs in milk, honey, and the substance of liver. Vegetable sugar is found in the sugar-cane (*Saccharum officinarum*) under the name of cane-sugar or saccharose ($C_{12}H_{22}O_{11}$), and in various fruits and grapes under the name of fruit-sugar, glucose, or grape-sugar ($C_{12}H_{24}O_{12}$). It also occurs in the stems of many grasses, and is made in the body by the action of the digestive fluids on starch, as well as by the liver, which organ begins the manufacture of a substance isomeric with starch, called glycogen, before birth, and continues its formation during life. All the starches and sugars of food are changed into glucose before they enter the blood-current. It is all conveyed to the liver, where it is changed into glycogen ($C_6H_{10}O_5$), which is gradually converted by a ferment found in the liver into animal sugar, which passes into the blood-current and is lost in the passage of this fluid through the lungs. The liver-sugar readily undergoes fermentation, and it may be changed into alcohol, which is rapidly converted into carbon dioxide and water.

6. During life the sugar is washed out of the liver as fast as formed, but it may be detected in its substance after death by appropriate chemical tests. During lactation the sugar of milk (lactose) exists in this fluid, and is normally discharged in conditions of health. If the glycogenic function of the liver be interfered with, as may happen in certain diseases of that gland, the sugars of digestion may pass unchanged through its substance into the circulating fluid, and be

eliminated by the kidneys, constituting glycosuria or the disease known as diabetes.

7. **Starch,** which is used as an article of diet, is derived from the vegetable kingdom. It is formed as grains of various sizes and shapes. It is formed in the chlorophyll-bearing part of leaves in the presence of sunlight. During darkness the starch which was formed in the leaves is rendered soluble by the addition of water, in which condition it visits the tissues of the plant as a food; the excess loses its water again, and is deposited as a food in the form of starch ($C_6H_{10}O_5$) in the various cereals—rye, oats, rice, corn, barley—and in the tubers of potatoes, yams, sweet potatoes, etc. When it is not used as a food by man or other animals, it acts as a food for the plant during the germination of the seed, when it becomes changed into sugar. Thus the young plant is enabled to live and grow at the expense of its reserve material, until it sends its plumule into the air and its roots into the soil, and begins its life over again, being nourished by the starch manufactured in its leaves and the matter absorbed by its roots. It is most abundant in rice, though it is found in tapioca (*Jatropha manihot*), sago (*Sagus farinifera*), the various varieties of arrow-root (*Maranta arundinacea*), tacca arrowroot, arum arrowroot, potato arrowroot, tous-les-mois arrowroot (*Canna edulis*), lentils, peas, and beans.

8. Starch-grains vary in size from $\frac{1}{9000}$ to $\frac{1}{350}$ of an inch in diameter; they are composed of two distinct substances—**starch granulose,** which is colored blue by aqueous solutions of iodine, forms the greater part of the grain, and is the part changed into sugar; **starch cellulose,** or **farinose,** which only forms from 2 to 6 per

cent. of the grain, is not so colored by iodine, and is not removed by the action of the saliva. It forms a skeleton of the grain when the granulose is removed.

9. Starch-grains appear under the microscope as if made of a number of layers concentrically arranged around a central or eccentrically placed nucleus. This appearance is not due to separate layers which have been successively deposited, but to layers containing different quantities of water, as completely dried starch-grains present no stratification.

10. Starch is insoluble in cold water, but when boiled, as in cooking, it becomes hydrated (absorbs water) and swells into a jelly-like mass. This takes place during digestion when raw starch is taken as food, and is further changed, before it can be absorbed, into dextrin, and then into sugar. These changes are effected very rapidly in the digestive cavities.

11. **Fats** are derived from both the animal and vegetable kingdoms. They form an important element in the diet of nearly all peoples, especially those living in cold climates. The important animal fats are generally taken in connection with the meats used, in the form of fatty (adipose) tissue, which consists of fat-vesicles or fat-globules developed in the connective tissue of the various parts.

12. The common animal fats are lard, suet, tallow, and butter. Butter is a peculiar fat. The other animal fats are composed of varying quantities of palmitine ($C_{51}H_{98}O_6$), stearine ($C_{57}H_{110}O_6$), and oleine ($C_{57}H_{104}O_6$). **Butter** contains a small quantity of oleine, a relatively large quantity of palmitine, and the fats which are peculiar to milk—viz. (the triglycerides of stearic, palmitic,

oleic, arachinic, capric, caprylic, caproic, butyric, and myristic acid. It also contains traces of acetic and formic acids and cholesterine (Heintz). These peculiar fats are sometimes called caproine, caprine, capryline, butyrine, etc. The decomposition of these fats and the liberation of the peculiar acids give rise to the disagreeable odor and taste of rancid butter.

13. Fats are also derived from the vegetable kingdom, occurring in the fruits, seeds, and grains of many plants. Indian corn contains nearly 9 per cent. of fat, and it occurs in less quantity in oats, rice, wheat, barley, and rye. Extracted from the fruit (drupe) of the olive tree (*Olea Europæa*), it is a liquid known as olive or sweet oil. The tallow tree of China (*Stillingia sebifera*), found also in India, Japan, and the tropical portions of America, yields a fruit containing three seeds which are thickly coated with a fatty substance. This is separated from the seeds as tallow, which is extensively used for manufacturing candles in China.

14. The fats are poor in oxygen, and are not true hydrocarbons (carbohydrates); that is, H and O do not exist in the proportion to form water, as they do in starch and sugar. They are not only introduced into the body from without, but are also formed within the organism; and this formation can take place upon a nitrogenous diet, the elements of which are changed partly into fat and stored up in the tissue, and partly into excrementitious matters (urea), which are discharged from the body. Fat, which is laid up in the body under conditions of excessive nutrition, is absorbed during hibernation, which is natural in some animals (the bear), and starvation. Sugar and starch are never

laid up in the body, but they are favorable to the formation of fat.

15. Fat is never discharged from the body in health, except in the milk during lactation, and is probably concerned in the production of animal heat, producing carbon dioxide and water. It has not, when used alone, the power to support life.

16. The inorganic principles are introduced into the body from without. Some of them are also formed within the organism (water, nitrogen, calcium carbonate, potassium chloride, sodium carbonate). They are discharged from the body in health, and are always combined with the organic principles, the single exception being the crystals of carbonate of lime (otoliths) found in the internal ear. Water is the most important of all the inorganic constituents of the body, occurring in every tissue of the organism, after which comes sodium chloride (common salt), which is found in all the tissues, fluids, and solids, with the exception of the enamel of the teeth. Calcium phosphate and calcium carbonate are the most important inorganic salts found in the bones and teeth.

17. The quantity of carbonate of lime found in bone varies, according to different authorities, from 76 to 113 parts per 1000. The quantity occurring in teeth varies with age, from 140 in an infant one day old to 100 in an adult, and 10 parts per 1000 in a person over eighty years of age (Lassaigne). The quantity of calcium phosphate in bone, according to the same author, is 400 parts per 1000, and the quantity in the teeth of the infant, adult, and octogenarian is respectively 510, 610, and 660 parts per 1000. Water forms nearly 70 per

cent. of the entire body. Iron is also a necessary constituent of the tissues. It is taken in the different foods and drinks, being a constant factor of milk, meat, and eggs.

SECTION V.

IMPORTANT ARTICLES OF FOOD.

1. **Milk** is one of the most important of all the articles of food. It contains all the alimentary principles necessary for nutrition, and is capable of meeting all the nutritive demands of the system when taken as a single article of diet. It is especially rich in the nitrogenous substances and fat, containing also inorganic principles and sugar. The following table will give the relative composition of cow's milk in 100 parts:

Water	86.8
Albuminoids	4.
Fats	3.7 to 4.50
Sugar	4.8
Salts	0.7

2. Butter is the fat of the milk-globules. It is obtained by beating or churning the milk for a considerable time, when the caseous envelopes are ruptured and the oil-globules are set free.

3. The milk-globules are formed in the epithelial cells lining the alveoli of the mammary glands, where they occur as droplets of fat in the substance of the cells. These unite or coalesce with each other to form larger drops after being discharged from the alveoli.

They measure from $\frac{1}{25000}$ to $\frac{1}{1250}$ of an inch in diameter, and are surrounded by a thin envelope of casein (Ascherson's membrane). The milk-globules are held in suspension in a clear or opalescent fluid, the milk-plasma. The globules and the plasma have a different refractive power, which produces the opacity of the milk.

4. If ether be added to a specimen of human milk and the mixture violently agitated, the fats are extracted. The fats in cow's milk will not be separated by this treatment unless acetic acid or caustic potash has previously been added to dissolve the albuminous envelope.

5. When pure and fresh, butter is one of the best fats to be used as an article of food, though all fats are probably the same when they reach the blood-current. Fresh butter has a characteristic smell and taste, and is of a yellowish-white color. True butter contains, in addition to the fat, some casein (3 to 5 grains in 100 of very good butter) and water (5 to 10 per cent.). It is frequently adulterated with beef and mutton suet, lard, and some vegetable fats, by the addition of various starches, by mixing it with milk and water and various mineral substances to increase its weight. Oleomargarine is the name of an artificial butter prepared from fresh beef suet by a process devised by Mege-Mouries. Butterine is the name of another substitute for butter, prepared by mixing animal fat with milk. This name is now discarded, and the name margarine is applied to all artificial butters. The fats used in adulteration are generally white, when they may be colored by annatto. Genuine butter may also be white. The various adul-

terations may be detected by appropriate chemical and microscopical tests. Under the microscope the fat of butter appears as oil-globules, while crystals (acicular and stellate) are generally found in the fats used in adulteration. Starch may be detected by the blue color after treatment with iodine. Crystals may appear in the fat of genuine butter after it has been melted and recongealed (Angell and Hehner).

6. The most important nitrogenized element in milk is *casein*. It is kept in solution by calcium phosphate, with which it is combined. Its spontaneous coagulation is due to the presence of a minute organism (*Bacterium lacticum*), which breaks up the sugar of milk into lactic acid and carbon dioxide. The casein of cow's milk is only three-quarters dissolved by the gastric and pancreatic juices, while that of human milk is all dissolved.

7. **Casein**, unlike albumen, is not coagulated by heat, but it is coagulated by acids and by ferments of both animal and vegetable origin. Rennet (obtained from the abomasus of the calf) in the presence of calcium phosphate converts the casein into cheese and soluble whey-albumin.

8. **Cheese** is very extensively used as an article of food. It is twice as rich in nitrogenous matter as meat, and contains one-third as much fat. (The fat in cheese varies in quantity according to the kind of milk from which it is prepared.) It is made by adding rennet to milk, when the casein is coagulated as curd, containing in its substance more or less fat. When cream is used cream cheese is produced. It contains 30.43 parts per 100 of fat; whole-milk cheese contains 20.54 parts per

100 of fat; skim-milk cheese contains 8.41 parts per 100 of fat (Bauer).

9. Cow's milk has a specific gravity of 1029 to 1034. The specific gravity of skim-milk is from 1032 to 1040; of cream, 1024. The milk of flesh-eating animals (Carnivora) is always acid in its reaction. Human milk is always alkaline in conditions of health. The milk of vegetable-feeders (Herbivora) may be either acid, alkaline, or neutral in reaction.

10. Many diseases may be communicated by the milk-supply. The germs may be derived from the diseased animals producing the milk, or be absorbed from the air, or taken from the water used in cleaning the vessels. Epidemics of diphtheria, enteric or typhoid fever, and scarlet fever have been traced to the milk-supply as the exciting cause, and there is strong reason to believe that many diseases occurring in cows can be transmitted to the human subject through the medium of the milk. Tuberculosis (consumption) can be contracted by drinking the milk or eating the flesh of an animal suffering with the disease, and the observations of Dr. Costello of the British army in India during an epidemic of pleuro-pneumonia which prevailed among the troops in 1875, point to the fact that this disease had its origin, in this instance, in the milk from pleuro-pneumonic animals.

11. The milk of cows affected with the foot-and-mouth disease (*Eczema epizootica*) has caused inflammation, ulceration, and diphtheritic-like exudations of the mouth with a swollen tongue, and an affection of the feet is reported to have occurred (Amyot). The milk from cows affected with the "trembles" produces

a milk-sickness characterized by great prostration, vomiting, constipation, swollen tongue, and diminished temperature. This disease has prevailed at different times, especially in the Western States, and the affection of the cows is supposed to be due to their eating the poison ivy (*Rhus toxicodendron*). Tyrotoxicon is the name of a poison found in milk by Professor Vaughan of the Michigan University. It was first found in cheese, and has been found in large quantities in ice-cream. It may be the cause of many cases of poisoning resulting from the use of the latter article.

12. The composition of butter is as follows:

Fats	88 in 100 parts.
Albuminoids	3.3 in 100 "
Water	6 in 100 "
Salts (variable)	2.7 in 100 "

13. The composition of cheese is as follows:

Fats	24.3 in 100 parts.
Albuminoids	33.5 in 100 "
Water	36.8 in 100 "
Salts	5.4 in 100 "

14. **Bread** is an important article of diet, containing such a variety of nutritive matters that it can support life, and does not become distasteful when prepared in the same manner and used for a long time. By baking, peculiar substances are developed which render it much more palatable and easier to digest than uncooked flour. It contains gluten (a vegetable nitrogenous compound), large quantities of starch, saline matters, and but a small quantity of fats. The finest flour is poorest in fats and relatively richest in starches. This is due to

the absence of the envelopes of the wheat-grains, which contain the salts and fats in largest quantities. Coarse flour containing the tunics of the wheat-grains presents the greatest variety of food-matters, though the bread is brown and coarse.

15. The dough from which bread is made should contain numerous little spaces or air-cavities. This makes the bread light, and enables the digestive fluids to penetrate it in all directions and properly prepare it for absorption. When bread is not porous, but is heavy and "sad," the digestive fluids less readily penetrate it, and, acting only on the exposed surface of the mass, while the interior remains unaltered, digestion is very much prolonged.

16. Carbon dioxide (CO_2) is generally the gas used to penetrate the dough and render it porous. This is generated in a variety of ways. In the preparation of "Danglish's patent aërated bread" it is forced through the dough by pressure. This is considered the best method of making bread. During baking CO_2 is formed by the decomposition of some of the sugar previously formed. By the action of minute organisms (*Saccharomycetes cerevisiæ*), which occur in the *leaven* or *yeast* used to make the bread "raise," CO_2 is also disengaged.

17. This is due to the decomposition of the sugar by the little plant, that it may get oxygen for respiration. It acts now as a ferment, producing heat, carbonic-acid gas (CO_2), and alcohol as products of the decomposition. Some of the starch is converted into sugar, yielding CO_2, during cooking. Small quantities of acids are also formed (butyric, lactic), and one of the

essential accomplishments of the baker is to arrest this change at the proper time. The various baking powders are compounds of ammonium carbonate, sodium carbonate, or bicarbonate, which when mixed with dough and acid (tartaric, citric, hydrochloric, etc.) disengage carbon dioxide gas. Commercial hydrochloric acid used in this way may be a source of poison, as it contains a small quantity of arsenic.

18. The composition of white wheaten bread of average quality is as follows:

In 100 parts—	
Carbohydrates	50.2
Albuminoids (nitrogenized matters)	7.5
Salts	1.6
Fats	1.5
Water	39.2

19. **Oats** (*Avena sativa*) were formerly extensively used as food by the inhabitants of the cool regions of Northern Asia and Europe. In the form of oatmeal it is more easily cooked than wheat, and is considered to be of greater nutritive value. It is rich in albuminoids, and contains large quantities of fat. Owing to the absence of adhesive matters, it cannot be made into bread. The composition of oatmeal, according to Letheby, is as follows:

Water	15	in 100 parts.
Albuminoids	12.6	in 100 "
Fats	5 6	in 100 "
Carbohydrates	63	in 100 "
Salts	3	in 100 "

20. **Rice** (*Oryza sativa*) is an important article of

food. It is a native of South-eastern Asia, and is said to furnish food for more people than any other plant. It is rich in starch, the grains of which are single (those of the oat are compound) and very easy to digest. It is poor in albuminoids, fats, and salts. In preparing for the table it should be steamed, and not boiled. When properly steamed the rice-grains, which are very small (.0003 inch in diameter), become much swollen, and are easily digested. There are several varieties of rice (red, brown, white). Its composition is as follows:

Water	10 in 100 parts.
Albuminoids	5 in 100 "
Fats	0.8 in 100 "
Carbohydrates	83.2 in 100 "
Salts	0.5 in 100 "

(*Letheby*).

21. **Maize** (*Zea mais*), Indian corn, is a native of the New World. It is now extensively grown in nearly all quarters of the globe. It furnishes food for many of the lower animals, and is also eaten by man. It is especially rich in fats, and, as it contains a rather large amount of indigestible matter, it should be thoroughly cooked before being eaten. Its composition, according to Poggiale, is as follows (cellulose excluded):

Water	13.5
Albuminoids	10
Fats	6.7
Carbohydrates	64.5
Salts	1.4

22. The disease pellagra (Italian leprosy, scurvy of the Alps), characterized by a wrinkled and scaly skin,

cramps, convulsions, diminished intellectual power, and blunted sensation, is supposed to be caused by eating corn in which is found a fungus (*Sporisorium madis*) (Verdet). This disease is supposed to exist in all regions where Indian corn is used.

23. The **pea** (*Pisum sativum*) and **bean**, pole bean (*Phascolus vulgaris*), field bean (*P. nana*), Lima bean (*P. lunatus*), English bean (*Vica faba*), are important articles of food. They are excessively rich in nitrogenized matter, contain some sulphur and phosphorus, and are richer in potash and lime than the cereals. They are rather difficult to digest, and if hard should be soaked and then thoroughly boiled before eating. The composition of dried peas is as follows:

Water	15
Albuminoids	22
Fats	2
Carbohydrates	53
Salts	2.4

(*Ranke*).

24. The **potato** (*Solanum tuberosum*) is a native American plant, cultivated now in many parts of the world, and, though extensively used as a food, it possesses little nutritive value. It is rich in vegetable acids and contains the salts of lime, potash, and soda in relatively large quantities. In the raw state its acid juice is an important article of food for those affected with scurvy, a disease characterized by muscular weakness, spongy gums, loose teeth, and general prostration. This disease, especially the variety called sea-scurvy (purpura nautica) is partly caused by cold, humid

atmosphere, and the prolonged use of one variety of food, especially salted fish and meats without vegetables. Potatoes are more nutritious when slowly and thoroughly steamed with the skins on. The starch-grains, which are large (.003 inch in diameter), are well cooked and the salts are not lost.

25. The sweet-potato (*Batatas edulis*) is used as food in warm countries, as the common potato is used in cooler climates. There are several varieties (red, white). It is more nutritious than the common potato, containing an excess of both sugar and starch. It is probably indigenous to both the Old and New Worlds, and its root sometimes reaches the weight of 50 pounds.

26. The composition of the common potato is as follows:

Water	74
Albuminoids	2
Fats	0.16
Carbohydrates	21
Salts	1

27. **Meats** form a most important article of food in the form of muscular tissue. Beef is considered more nutritious than the flesh of birds or fishes. The flesh of vegetable-feeding animals (*Herbivores*) is more generally used as food than that of carnivorous animals, and can be taken for a longer time without becoming disagreeable to the taste. All meats are rich in nitrogenous matters, and many contain much fat and salts. They are easily digested and assimilated, and the tissue-changes are very rapid in those animals living exclusively on flesh. Meats are deficient in starch, but con-

tain considerable quantities of salts—chlorides and phosphates.

28. As many diseases can be contracted by eating meat, it should always be carefully examined and well cooked. The disease called **trichinosis** is caused by eating pork containing a parasite encysted in the fibres of the flesh, and called the *Trichina spiralis*. After gaining access to the alimentary canal of man, this multiplies very rapidly, becomes sexually mature, produces grave disorders of the intestinal tract—nausea, vomiting, colic, diarrhœa or constipation, swollen face, dry tongue, parched lips, fever of a typhoid type, and intense thirst. It penetrates the tissues or is carried by the blood- or lymph-currents, bores its way into the muscles, causing muscular swellings, with intense soreness and pain, which increase with each movement. It invades the muscles of the mouth, ear, and eye, causing disturbances of sight and hearing and difficulty in mastication and deglutition. The proportion of infected pork is given by Dr. Sutton at from 1 to 20 per cent.

29. The tapeworm (*Tænia solium*) is introduced into the alimentary canal of man by eating the flesh of "measly pork." This appearance of the meat is due to the presence of an embryonic parasite (*Cysticercus cellulosus*) in the flesh of the pig. It is generally large enough to be seen with the unaided eye, but is best viewed with a microscope of low power. It may range in size from $\frac{1}{25}$ to $\frac{3}{4}$ of an inch in length, and have a diameter of from $\frac{1}{34}$ to $\frac{1}{2}$ of an inch.

30. In cooking, meat loses from 20 to 35 per cent. in weight. This is mostly water, and the loss is greater

when meat is roasted than when boiled or stewed. When boiled, the meat should be in as large a piece as convenient (cutting in small pieces favors the loss of salts), and should first be immersed in boiling water for five or ten minutes. This coagulates the albumen, after which the heat must be low. When roasted, the meat should be subjected at first to a very intense heat. This forms a crust and prevents the loss of the juices; after this it should be roasted slowly with a low heat. When the heat is too great, the muscular fibres become dry, hard, and indigestible. Beef yields a very weak broth (one pint containing 96 grains of salts and 148 grains of albuminoids). Chicken makes a more nutritious broth than either beef or mutton.

31. The following is the composition of meat, according to Ranke:

Best quality beefsteak (little fat):

Water	74.4
Fats	3.5
Albuminoids	20.5
Salts	1.6

Roast or boiled meat, with dripping:

Water	54
Fats	15.45
Albuminoids	27.6
Salts	2.95

Salt pork:

Water	44.1
Fats	7
Albuminoids	26.1
Salts	22.8

Smoked ham:

Water	27.8
Fats	36.5
Albuminoids	24
Salts	10.1

(*Konig*).

Poultry:

Water	74
Fats	38
Albuminoids	21
Salts	1.2

(*Letheby*).

Chicago corned beef:

Water	52.2
Fats	14
Albuminoids	23.3
Salts	4

32. **Eggs** contain all the essential food-materials. The white contains egg-albumin, with a small quantity of saponified fats (olein and palmitin, with soda), sugar, extractives, and salts. The yelk contains fats, albuminoids, and iron. An egg weighs from one and three-quarters to two ounces, one-tenth of which is shell.

33. The composition of egg (10 per cent. of the weight deducted for the shell) is as follows:

Water	73.5
Albuminoids	13.5
Fats	11.6
Salts	1.4

Yelk:

Water	51.5
Albuminoids	15
Fats	30
Salts	1.5

White:

Water	84.5
Albuminoids	13.5
Fats	3
Salts	1.3

34. **Alcohol** is a stimulant, and not a necessary food. It may act temporarily as a nutritive substance in the absence of sufficient food, but when the tissues are supplied with it for a considerable length of time, they lose their power to assimilate true food-materials, and the desire for alcohol is increased. After alcohol is taken in quantity, it is found in nearly all tissues of the body, especially in the nervous substance and liver. It diminishes tissue-waste, lessening the elimination of urea and carbon dioxide. All the normal functions increase the nutritive processes and the amount of effete matter discharged.

35. Alcohol is probably formed in the blood from the sugar thrown into the current from the liver and oxidized into carbon dioxide (CO_2) and water (H_2O), with the production of animal heat. This fact explains the efficacy of alcohol when used in conditions of disease characterized by fever and the rapid destruction of tissue-substance. It is oxidized, forms heat to "feed" the fever, and prevents, to that extent, the consumption of the tissues of the body. It is the almost universal testimony of all physicians in civil and military life, as well as of those accompanying voyages to the polar regions and expeditions through hot climates, that when there is sufficient food, alcohol is not only not beneficial, but positively injurious, and when taken at all it should be at the end of the day and in quantity

not exceeding one and a half to two ounces. When given in small quantities in hot water (one ounce of alcohol to one pint of water), it has the power to keep off the cravings for food and prevents the "gnawing at the stomach."*

36. It is now generally accepted that when alcohol is taken in small quantities, it is consumed in the organism, and when large quantities are used, the excess is eliminated by the kidneys, alimentary canal, the cutaneous and respiratory surfaces. The peculiar odor of the breath of an alcoholic is due to certain volatile substances, one of which is fusel oil (Figs. 65, 66).

37. **Spirits** (rum, gin, whiskey, brandy), beer, and wines are some of the most important beverages containing alcohol. These drinks are prepared by fermentation and distillation. The alcohol found in beer is due to fermentation caused by the yeast-plant (*Torula cerevisiæ*); that found in wine is caused by the growth of another species (*Saccharomycetes ellipsoideus*). These organisms take their nourishment directly from the sugary mixture of the wort and must, and elaborate within their cells a variety of substances, among which are glycerin, carbonic acid, and alcohol.

38. In the manufacture of wine, when there is not sufficient nitrogenized matter present in the after-fermentation, the sugar is not all destroyed, and sweet wine is produced. Most wines contain a small quantity of fats, acids (malic, tartaric, acetic; tannic in port,

* *Notes of Surgeon Ambler of the Steamer Jeannette on the Polar Expedition of 1879–81.* More than two fluidounces will diminish the power of doing bodily labor; less than this has no appreciable effect.

madeira, and Rhine wines, absent in champagne, glucic, carbonic, with some fatty acids—butyric, formic), fruit-sugar, salts, nitrogenized matters, and ethers (caprylic, pelargonic, acetic, caproic, and others). There are twenty-five or more compound ethers in wine (Dupré). The pleasant odor of wine is due to the presence of œnanthic ether, and the flavor or bouquet, which develops with age, to volatile ethers and extractives. In the manufacture of brandy the liquid is distilled after fermentation, and the vapor passed through hot charcoal, which separates the fusel oil from the alcohol.

39. Brandy contains from 50 to 60 per cent. of alcohol; whiskey, the same; and rum, from 60 to 75 per cent. Among the wines, madeira, sherry, port, and marsala contain from 15 to 25 per cent. of alcohol; red Bordeaux, from 6 to 13 per cent.; white Bordeaux wines, from 11 to 19 per cent.; champagnes contain from 6 to 13 per cent. of alcohol; and the Rhine wines, 7 to 16 per cent. The alcohol in beer is from 1 to 5 per cent.; in porter and ale, from 1 to 10 per cent. The tissue-forming power of beer depends upon the presence of phosphoric acid and the potash salts. It diminishes the discharge of both fatty and nitrogenous substances from the system, causes loss of appetite when used in excessive quantities, imperfect oxidation, and the formation of poisonous matters in the blood.

40. The observation of nearly all persons goes to prove that the intemperate use of any and all beverages containing alcohol diminishes the powers of both mind and body, predisposes to diseases of various kinds, destroys the normal structure of nearly every tissue in

the system, induces premature old age, and lessens the period of life.

41. The following is a table showing the chances of life in the temperate and intemperate, according to Neison:

An intemperate person's chance of living is—

At 20 years of age	=	15.6 years.
At 30 "	=	13.8 "
At 40 "	=	11.6 "
At 50 "	=	10.8 "
At 60 "	=	8.9 "

A temperate person's chance of living is—

At 20 years of age	=	44.2 years.
At 30 "	=	36.6 "
At 40 "	=	28.8 "
At 50 "	=	21.25 "
At 60 "	=	14.285 "

42. The average duration of life after beginning the habit of intemperance is—

For laboring men, mechanics, etc.	18 years.
For merchants, traders, and commercial men	17 "
For professional men	15 "
For females	14 "

43. The death-rate is higher where two or more kinds of intemperate drinks are used than when one only is taken. The following figures will show this: In spirit-drinkers the mortality is nearly 60 in 1000; in beer-drinkers it is a little over 45 in 1000, while in beer- and spirit-drinkers it is nearly 62 in every 1000. The relative average death-rate will be grossly repre-

sented by 6, 4, and 7 per cent. This shows the great advantage of the temperate class at all ages.

44. Alcoholic beverages, in some form, have been used since the earliest times by nearly all the nations of the earth. History gives no account of their first production, and the origin of the art is lost in the mists of antiquity. Egypt is probably the country where beer was first brewed. Noah was acquainted with the wine from the grape, and Theophrastus (400 B. C.) described the "wine of barley" (beer).

45. The true cause of fermentation was not known until 1835, when Cagniard de la Tour of France and Schwann of Germany saw the organism (*Torula cerevisiæ*) bud and grow in the yeast. This plant had been seen long before by Leeuwenhoek (1680), but the microscopes of his time were too imperfect to study its growth and development.

SECTION VI.

THE DIGESTIVE FLUIDS.

1. The most important digestive fluids are the *saliva, gastric juice, bile, pancreatic fluid,* and the *intestinal juice.*

2. The **saliva** is the digestive fluid found in the mouth, and is furnished mainly by the salivary glands, though the mixed saliva contains, in addition to the products of these glands, secretions from the labial and buccal glands, the glands on the hard and soft palate, the tonsils and pharyngeal glands, and those covering the dorsum, edges, and tip of the tongue. The secretions from the mouth, with desquamated epithelium

and leucocytes, produces the opacity of the mixed saliva.

3. The **parotid saliva** is formed by the parotid gland, which is below and in front of the ear, and is the largest of the three true salivary glands. The parotid saliva is discharged into the mouth through Steno's duct, which opens on the internal surface of the cheek near its middle, opposite the second superior molar tooth. This position of the duct favors the complete admixture of the parotid secretion with the food during mastication, whereby it becomes moist and is prepared for deglutition. This secretion is more liquid than that from the other salivary glands. It contains an organic matter which is coagulated by heat and alcohol, and a peculiar chemical compound (sulphocyanide of sodium or potassium) not found in the saliva of the dog or sheep (Brettel). It has a chemical as well as a mechanical action on food.

4. The **submaxillary gland** is intermediate in size between the parotid and sublingual glands. It is situated in the submaxillary fossa, on the internal surface of the body of the inferior maxillary bone, below the mylo-hyoid ridge, and discharges its secretion—the submaxillary saliva—through a duct which runs under the tongue and opens by a small opening at the side of the frenum. This is called *Wharton's duct*, and its opening is indicated by a small eminence or papilla. This secretion is rather thick and viscid, and sets into a jelly-like mass when cooled. Its organic matter is not coagulable by heat. Being thick and viscid, it cannot become so thoroughly mixed with the food as the parotid secretion. It has a chemical and mechan-

ical action on the food, coating the mass with a glairy coat which facilitates its passage into the stomach. It also contains a small quantity of the sulphocyanide of potassium or sodium.

5. The **sublingual** is the smallest of the salivary glands. It is situated in the sublingual fossa, on the inner surface of the body of the inferior maxillary bone, above the mylo-hyoid ridge, external to the genial tubercles. These glands discharge their secretion—sublingual saliva—by fifteen to twenty ducts into the mouth by the side of the frenum. One of these (*ductus Rivinianus*) is of large size, and empties into the duct of Wharton before it opens into the mouth.

6. The **sublingual saliva** is the most viscid of all the secretions found in the mouth. It does not gelatinize when cooled. It contains large quantities of mucin, together with corpuscles (*salivary*) and a very small quantity of sulphocyanide of potassium. It coats the mass of food with a mucilaginous covering, to cause it to pass easily through the pharynx and œsophagus. It also has a chemical action on food.

7. The flow from the parotid glands is increased during the act of mastication, and especially when sapid substances are taken. It is greatest upon the side which is most active. The flow from the submaxillary glands is also increased during mastication, but the flow is no greater on one side than on the other. That from the sublingual glands is increased by the introduction of sapid substances into the mouth, which is less than that from the submaxillary glands, due to the same cause.

8. The **mixed saliva** is an opalescent, colorless, odor-

less fluid, without taste, slightly viscid, and sometimes frothy; alkaline in reaction, with a specific gravity of 1004 to 1006 or 1009. The quantity secreted in twenty-four hours varies from two and a half to three pounds. During diseased conditions of the system the saliva may be acid in reaction, as is the case in fever, when its action as a ferment also diminishes, and when the fever is high it ceases to be formed. It is also acid during excessive anger and other emotions, and in inflammations of the mouth. In the disease characterized by sugar in the urine (diabetes mellitus) the saliva may contain sugar, which ferments, producing an acid that changes the reaction of the fluids of the mouth.

9. The active principle of the saliva is a substance called *animal diastase* (Mialhe) or *ptyalin* (Berzelius). It is very powerful in the conversion of hydrated starch into dextrin, maltose ($C_{12}H_{22}O_{11} + H_2O$), and finally into glucose ($C_{12}H_{24}O_{12}$). This ferment is absent from the saliva of new-born children (except that from the parotid gland) until about the second month, when it is found in the secretion from the submaxillary glands.

10. The secretion of saliva is diminished by nearly all the narcotics (soporifics, anodynes). Small doses of nicotia increase the flow, but large doses dry up the secretion by paralyzing the secretory nerves (chorda tympani). Many drugs act upon the salivary glands to increase their activity (nicotin, mercury, pilocarpin, physostigmin), as do some narcotics (anæsthetics)—chloroform, ether; and condiments, such as vinegar, pepper, mustard, ginger, horseradish, salt, onions, and garlic, which contain in some cases pungent principles with essential oils that act directly on the sensory

nerves of the mouth, influencing the flow of saliva reflexly.

11. During mastication the parotid saliva is thoroughly mixed with the food, as well as small quantities of the submaxillary and sublingual secretions, acting mechanically to soften the bolus and to coat it over with a glairy coat. The saliva converts hydrated (cooked) starch into sugar (glucose, $C_{12}H_{24}O_{12}$) after causing the intermediate changes already mentioned, but acts very feebly in converting raw starch. Its power to transform starch into sugar depends upon the ptyalin, and any substance which increases or decreases the activity of this substance increases or diminishes salivary digestion.

12. All the varieties of the human saliva have the same power to change starch into sugar. This change takes place best in the mouth in the normal alkaline saliva, but the saliva may continue its action in the stomach in a neutral or even acid medium, when the acid condition of the contents of the stomach is due to the presence of an organic acid.

13. Alcohol renders the saliva powerless to act upon starch by destroying the ptyalin. Oxygen and carbon dioxide, which are carried into the stomach in small quantities by the saliva, and chloride of sodium or common salt, all increase the activity of this fluid. Wines, on account of the alcohol and acids they contain, are highly detrimental to salivary digestion. The same may be said of tea, which arrests altogether the action of the saliva. This inhibitory action of tea depends upon the tannic acid it contains; hence the importance of drinking the tea after the completion of

the meal. The action of coffee on salivary digestion is almost negative.

14. The action of the saliva is supposed to be negative upon all alimentary principles except the starches, though other ferments, having the power to digest albumens and form peptones, have been described as existing in the human saliva (Kühne, Munk). In addition to the ferments named, the alimentary canal is probably teeming with innumerable forms of microscopic life which may play some very important rôle in the process of digestion. Already the great French chemist and biologist Pasteur has captured and studied the life-history and action of many of these microorganisms from the mouth, some of which act upon organic nitrogenized principles, while others convert starch into sugar.

15. The **gastric juice** is secreted by the mucous membrane of the stomach and the glands imbedded in its substance (Fig. 64, *A*). The quantity secreted in twenty-four hours is from eight to fourteen pounds. It is of a pale straw color or clear, has a saline taste, with a peculiar odor after standing some time, though odorless when fresh. It is distinctly *acid* in reaction, with a specific gravity of 1005 to 1009. Normal gastric juice always contains an organic nitrogenous ferment called *pepsin*, which, with the free hydrochloric acid, gives to this fluid its digestive properties. Lactic acid is also present in the gastric juice, probably as a product of gastric fermentation.

16. Any fluid in the stomach which is not acid, and does not contain pepsin, is not true gastric juice. The acid of the gastric juice is free hydrochloric, with a

small quantity of lactic, though the ferment is active in the presence of other acids (phosphoric, tartaric, citric, malic, oxalic, acetic, sulphuric, lactic); and when the normal acid is destroyed in the formation of salts from liberated bases, the digestive processes in the stomach continue uninterrupted.

17. The color of the mucous membrane during the intervals of digestion is pale, and there is not much fluid covering it. Upon the introduction of food through the natural passages it becomes swollen and velvety and of a rose-red color. Very soon it begins to weep, and little clear drops appear on its surface, which, increasing in size, run together and form the gastric juice. The motions of the stomach cause the food to pass over its internal surface, and the gastric juice is wiped up and absorbed, being replaced by fresh secretion.

18. During fevers and inflammatory conditions of the stomach, after excessive eating and drinking, profound mental emotions, as anger and fear, the character of the gastric juice becomes so changed as to have no power in preparing the contents of the stomach for absorption. Frequently during the course of a fever the gastric juice ceases to be formed, and the mucous membrane of the stomach becomes dry and red and excitable, and the slightest impression or irritation produces vomiting. In conditions of this kind food is absorbed slowly, if at all, often lying in the stomach for an entire day unless ejected by vomiting, while liquids are taken up with great avidity. The quantity of free acid in the gastric juice of fever patients is much diminished, and often absent (Hoppe-Seyler).

19. Gastric digestion is retarded by beer, tea, and

coffee. Wines have a similar effect. Very small quantities of brandy, rum, or whiskey are supposed to promote the action of the gastric juice, while large quantities arrest it altogether.

20. Certain vegetable substances containing a bitter principle facilitate gastric digestion in conditions characterized by loss of appetite and impaired nutrition (quinine, gentian, quassia, chamomile), while others pervert it (strychnia, morphia, veratria). The continued use of alcoholic beverages destroys the healthy mucous membrane of the stomach, producing local inflammations, followed by ulceration (Figs. 65, 66).

21. The gastric juice has important preservative properties. It will not only resist putrefactive changes, but will prevent, and even arrest, them when they have progressed to a considerable extent; hence tainted meat and other articles of food are frequently taken without injury.

22. The action of the gastric juice upon starch, so far as its power to convert it into sugar is concerned, is negative, but it dissolves away the farinose or starch cellulose, liberating the granulose, which is changed into sugar in the small intestine. On account of the acid reaction of the gastric juice and the elevated temperature presented by the stomach, raw starch is hydrated, and hydrated or cooked starch passes into the small intestine unchanged. The action of the gastric juice on starch must be considered as preparatory and not final.

23. The sugars of which glucose ($C_{12}H_{24}O_{12}$) may be taken as the type are unaffected by the secretions of the stomach, and are probably absorbed, without special

preparatory changes, directly by the gastric mucous membrane. The sugars of which cane-sugar ($C_{12}H_{22}O_{11}$)

Fig. 65.



Vertical section through the stomach, showing the arrangement of its mucous membrane in longitudinal folds at 7, 7, 7, 7, and five ulcers as the result of the moderate use of alcohol; 4, œsophagus; 5, greater curvature of the stomach; 6, lesser curvature; 1, gall-bladder; 2, the common opening of the bile and pancreatic ducts into the duodenum; 3, duodenum; 8, pylorus; 9, 9, 9, 9, shows transverse folds of the mucous membrane of the small intestines (*Valvulæ conniventes*); 10, 10, ducts from the liver.

may be taken as the type are slowly changed into $C_{12}H_{24}O_{12}$ in the stomach. This change is necessary, as cane-sugar, as such, will not be absorbed by the mucous membrane of the digestive tract, and if introduced arti-

ficially into the blood-current it will not be used by the tissues, but is promptly discharged by the kidneys as effete matter unfit for nutritive purposes.

24. The action of the gastric juice upon fats is negative when the oil-globules are not surrounded by a membrane. When they are taken as food in the form of adipose tissue mingled with various kinds of meats, those vesicles which are not ruptured by the teeth during mastication are dissolved by the gastric juice, thus liberating the fat from its albuminous envelope, when it becomes liquid at the temperature of the stomach, and, passing into the small intestine, receives its final preparation for absorption.

25. The action of gastric juice upon the nitrogenized alimentary principles is a very important one. It not only dissolves them, but acts chemically upon them in such a way that they are easily absorbed and promptly assimilated.

26. Upon meat the action of the gastric juice is also preparatory and not final. It dissolves away the connective tissue which holds the fasciculi and bundles together (endomysium and perimysium), destroys the albuminous sheath of the muscular fibres, sarcolemma, and liberates the muscular substance, which passes into the small intestine in the form of very small pieces, which still present the transverse striations where its digestion is completed, and it finds its way into the circulation.

27. The action of the gastric juice on the proteids or albuminoids as they are found in vegetable nitrogenized substances, casein, fibrin, and albumen, is to convert them first into an acid albumen or syntonin (Mul-

der), then into hemialbuminose (Kühne) or propeptone (Mulheim), and finally into true peptone. This action depends upon the presence of the pepsin and the acid. The action of the pepsin seems to be continuous; that is, the pepsin can peptonize new albumen if the quantity of hydrochloric acid be kept at the proper standard.

28. The casein of milk is first coagulated by the gastric juice, and then dissolved. It is called casein-peptone, and is absorbed from the stomach. Coagulated casein, as it is found in cheese, is dissolved slowly and disposed of in the same way. The casein of human milk is precipitated in the form of a jelly, and is easier digested than the casein of cow's milk, which is precipitated as a firm curd.

29. Coagulated albumen as it occurs in the cooked white of egg is dissolved by the gastric juice, and finally converted into an albumen-peptone, and absorbed from the stomach. Raw albumen as it occurs in the uncooked white of egg is composed of globules of albumen contained within delicate albuminous envelopes. The gastric juice dissolves the membranes and changes the albumen into an albumen-peptone, which is absorbed from the stomach. Cooked albumen is more difficult to digest than raw albumen. Gelatin is converted into gelatin-peptone, fibrin into fibrin-peptone, and gluten into gluten-peptone. These peptones all agree in certain properties, yet each differs in certain particulars from all the others.

30. Albumen is coagulated by heat and acids. It will not readily pass through animal membranes (is not osmotic); unacted upon by gastric juice, it will not be absorbed by the mucous membrane of the digestive

tract; and if the barrier offered by the absorbing surface of the alimentary canal to its entrance into the circulation be overcome by artificial injection into the blood-current, the tissues refuse to assimilate it, and it is discharged from the system by the kidneys as an inert substance.

31. Peptones differ from albumens in that they will not be precipitated by heat or acids. They will pass through animal membranes with ease (they are osmotic); therefore will be absorbed by the surface of the alimentary canal; and once in the blood-current, whether by natural absorption or artificial injection, they will be assimilated by the tissues and act as constructive matter for the different parts of the body. They are precipitated by some of the metallic salts, by tannic acid, the acids of the bile, and by alcohol. Alcohol also precipitates pepsin, and is thus detrimental to gastric digestion in two ways.

32. The duration of stomach digestion must vary with the quantity and quality of the food taken, the thoroughness of mastication, and the condition of the digestive organs. During the time the food is in the stomach it is passed along the greater curvature toward the small end, and back along the lesser curvature to the large end, the passage requiring two or three minutes. Shortly after the introduction of food the stomach becomes divided by its muscular fibres into two pouches or divisions, the greater one at the cardiac end, and the smaller one at the pyloric end. The movements in the greater pouch are slow, regular, and feeble as compared with those in the smaller pouch, which are irregular and forcible. The food generally

begins to pass into the duodenum in from fifteen to twenty minutes after ingestion, and continues for three or four hours or until the stomach is empty.

33. The gastric juice is absorbed when it has performed its function, and but a small quantity of it is found in the stomach at any one time. The mucous membrane of the stomach is protected from the action of the gastric juice by the alkalinity of its circulating blood.

34. The bile is discharged from the cystic and hepatic ducts through the ductus communis choledochus, which opens, in common with the main duct of the pancreas, into the descending portion of the duodenum. In the human subject it is of a dark-brown or golden color, alkaline in reaction, with a specific gravity which varies in health from 1018 to 1032. It is slightly viscid from an admixture with mucin, though in many acute diseases it becomes very thin and watery and may cease to be formed.

35. The exact part the bile plays in digestion is unknown. It acts upon fats in such a way that they are absorbed by the lacteals or pass through the epithelium of the small intestine into these vessels. Its action on neutral fats is probably a true emulsionization, and not a decomposition into a fatty acid and glycerin. The soaps which are formed by the bile increase its power to emulsify fats. They may result from the breaking up of the biliary salts into bile-acids and bases, the latter (soda) uniting with the fatty acids to form soluble soaps.

36. The quantity of bile secreted in twenty-four hours is not far from two and a half pounds. It is the

natural cathartic, and is a disinfectant and deodorant. It stimulates the walls of the intestine and the muscular tunic of the villi contract, expelling the contents of the contained lacteals. It thus acts to facilitate mechanically the absorption of fats.

37. That bile is essential to life seems proved by the fact that when it is discharged from the body of an animal through a biliary fistula, and not permitted to enter the intestine, the animal constantly loses weight; the fæces become light-colored and have a disagreeable odor; fat appears in large quantities in the dejections; fatty articles of food become highly distasteful, and are finally refused, though other substances will be taken with avidity. This will continue until four-tenths of the weight is lost, when the animal dies, notwithstanding the fact that the appetite has been preserved and a sufficient variety and quantity of food has been taken.

38. The progressive emaciation characterizing animals with a biliary fistula is supposed to be due to the loss of the constituents of the bile, especially the bile-acids, which are normally absorbed, and the fats, which are not rendered fit for absorption by the other fluids. Animals of this kind have a voracious appetite and will eat an unusual amount of food. Some authorities believe that, as the bile contains a ferment which has the power to change starch into sugar (Jacobson, Nasse), the starches are capable of replacing, to a certain extent, the fats, and that the animals may even increase in weight, not by the deposition of adipose tissue, but by the increased formation of the fleshy parts of the body.

39. In addition to the function of the bile as a

secretion, it is probably also an excretion, discharging a substance found in the spleen, crystalline lens, blood, and nervous system under the name of cholesterin. This is an excrementitious substance, first definitely described by Austin Flint, Jr., in 1862. It is formed in largest quantities in the brain, and is separated from the blood by the liver as an effete product of nervous activity. When it accumulates in the blood and tissues as a result of functional or organic diseases of the liver, it gives rise to an abnormal condition called cholesteræmia. When it reaches the intestinal canal, it undergoes a change, and is discharged with the fæces under the name of stercorin. Bile is the only digestive fluid formed during fœtal life. It is then, probably, purely an excretion.

40. The liver has still another function (glycogenic), which may be called its manufacturing function. It forms glycogen, which in a changed form is thrown into the blood-current. It is a halting-place for the hydrocarbons, where they are modified and utilized to meet the metabolic requirements of the various tissues. The ferment found in the liver-cells is probably derived from the blood, or from the destruction of red blood-cells constantly going on within the substance of the liver, furnishing materials for the formation of bile.

41. The liver-cells, which measure but $\frac{1}{1000}$ of an inch in diameter, are the structures concerned in the formation of glycogen, the secretion of bile, and the excretion of cholesterin.

42. The **pancreatic juice** is formed in the pancreas, a compound tubular gland resembling the salivary glands in structure and power of secretion. It is some-

times called the abdominal salivary gland. It lies transversely across the upper part of the abdominal

Fig. 66.



INTERIOR OF THE STOMACH, SHOWING NUMEROUS ULCERS RESULTING FROM THE EXCESSIVE USE OF ALCOHOLIC DRINKS.

1, œsophagus; 2, greater end or fundus of the stomach; 3, greater curvature; 4, lesser curvature; 5, pyloric end.

cavity, behind the peritoneum. It is from six to seven inches in length, one to two inches wide, three-quarters of an inch thick, and weighs about five ounces. It is composed of a body, a large end or head which is in relation with the duodenum, and a narrow end or tail which is in relation with the spleen. It discharges its secretion into the duodenum by two ducts, the main one opening with the ductus communis choledochus, and the smaller one about an inch above the common duct.

43. The pancreatic juice is an opaline or colorless, viscid fluid, without odor and of a faint saline taste, strongly alkaline in reaction, with a specific gravity of 1019 to 1040. It coagulates into a firm mass upon the application of heat, and rapidly undergoes putrefactive changes when removed from the body. Its most important constituent is an organic ferment called pancreatin, which is now known to be composed of at least three, and probably four, distinct substances.

44. This fluid acts vigorously upon starch, both raw and cooked, converting it into sugar. It also converts cane-sugar ($C_{12}H_{22}O_{11}$) into grape-sugar, which undergoes no further change before absorption. This action is due to a ferment supposed to be identical with ptyalin, called *amylopsin*.

45. The action of the pancreatic juice on albuminoids or proteids is to convert them into pancreatic peptones, which are sometimes called tryptones. It is a true peptone ready to be absorbed, and is the final product of the action of the pancreatic juice on albuminoids. The ferment that works this change is called *trypsin* by Kühne. It is the *pancreatin* of Corvisart, and its activity is increased by the presence of the bile and the previous action of the gastric juice.

46. The pancreatic fluid is the only digestive juice capable of striking a permanent emulsion with fats. It also has the power to "split" fats into fatty acids and glycerin. This action is due to a very unstable ferment called *steapsin* (Claude Bernard's fat-splitting ferment). Its action is encouraged by the presence of the bile. The action of the pancreatic juice in preparing fats for absorption is very important, and when it is

altered in composition or quantity by pressure upon the pancreatic ducts or disease of the gland itself, the fats pass out of the intestines unchanged. The action of the pancreatic juice is essential to life, as is proved by cases of death resulting from destruction of the gland. The action of the pancreas is continuous in the vegetable-feeders, but is suspended during the intervals of digestion in man and the carnivorous animals.

47. The **intestinal juice** is the third digestive fluid encountered in the small intestine. It is formed mainly by the follicles of Lieberkühn. Like the pancreatic juice, the quantity formed in a given time cannot be definitely ascertained. It is viscid and pale-red or yellow in color. In the dog it is rather thin, with a specific gravity of 1012. It changes starch, both raw and cooked, into grape-sugar, but its action on cane-sugar is negative. Albumens and meats, especially when cooked, are digested. The ferment is probably formed in the glands of Brunner, but its nature is unknown. The action of the intestinal juice on fats is negative.

48. The function of the large intestine (ascending, transverse, and descending colon, sigmoid flexure, and rectum) is mainly to receive the refuse and indigestible matter.

QUESTIONS.

SECTION I.

Is there permanency in any division of organic nature? Does protoplasm ever remain unchanged for a longer or shorter period of time? Under what conditions? How does it indicate that it lives?(1). What change takes place with tissue-work? What must the tissues of the body

do that they may live? Where do they get their nourishment?(2). What are the sources of supply for the blood? Whence is the alimentary canal replenished? What is the relation of life and death as applied to the tissues of the body?(3). What creates the sensations known as hunger and thirst?(4). What is hunger?(5). What is thirst?(6). What condition is produced when the demands of hunger and thirst are not satisfied?(7). Is the demand by the tissues greater for air, water, or solid food? How long can life exist without food or drink? How does age influence the power to do without food?(8). Is the stomach the seat of hunger?(9). To what parts is the sense of thirst generally referred? Why? Where is the true seat of the want?(10). How may it be demonstrated that the sense of thirst is not in the mouth and throat solely?(11). What is a gastric fistula? When and by whom was the operation first done? Had any been described previous to that time? What do you know of Alexis St. Martin?(12).

SECTION II.

What is the alimentary canal? What is its function in the higher animals?(1). Tell what you know of the alimentary canal in some of the lower forms of animal life(2). What is peculiar about the alimentary canal of the clam? How is it in fishes and amphibians? In what kind of animals is a gizzard found? What is its function? Is it well developed in the birds of prey?(3). Is the alimentary canal long or short in flesh-eating animals? How is it in vegetable-feeders? Why is it longer? How long is it in the full-grown ox? How long is it in man? Why is it relatively short in carnivorous animals?(4). Name the divisions of the alimentary canal in man(5). What will follow a description of the divisions of this canal?(6). Describe the lining of the alimentary canal(7). What is prehension? Name some organs of prehension(8). What is the mouth? What does it generally contain?(9). In what condition must the food be before it can be absorbed? What is the function of the teeth? Is it conducive to health to eat rapidly? Why not?(10). How many permanent teeth in man? How many milk teeth? How many kinds of teeth are there in man? Name the parts of a tooth(11). What are the crown, neck, root?(12). Describe the crown and its covering of enamel(13). Describe the covering of the fang. What covers the enamel? How thick is it? What is its function? Is the enamel ever reproduced when destroyed?(14). Describe dentine; the pulp-cavity(15). Describe the incisor teeth. How many have the elephant, lion, ox, squirrel, sheep, rabbit?(16).

Describe the canine teeth. Why are they called by this name?(17). Describe the premolars, telling how they differ in size and number of roots(18). Describe the molar teeth? What is the third molar called? (19). At what ages do the incisors, canines, premolars, and molars appear?(20). What is the function of the teeth, tongue, lips, and cheeks?(21). Describe the passage of food from the mouth into the stomach(22). Describe the pharynx(23). Name the opening leading into or out of it(24). What is the function of the epiglottis? of the soft palate?(25). Describe the stomach. What is peculiar about the stomach of the crocodile, the crab and lobster, the horse, the porpoise? How many divisions in the stomach of ruminants? Name and describe them. Describe the passage of food through the four compartments (26). What surrounds the gullet as it passes through the diaphragm? Does it facilitate or retard emesis at the end of an inspiratory act?(27). Give the location of the stomach, name its parts, and tell its dimensions and weight(28). How many coats has the stomach? Describe the muscular coat(29). Describe the mucous coat(30). What produces the honeycomb appearance of the mucous membrane? What is their diameter?(31). Where do these little openings lead?(32). How many main varieties of glands in the human stomach? Describe the peptic glands. What do they secrete? By what other name are they called?(33). Describe the acid glands(34). What is the function of the acid glands? By what other name are they known?(35).

SECTION III.

Name the divisions of the small intestine. What is the length of each? How many coats has it?(1). Describe the mucous membrane of the small intestine. What are the valvulæ conniventes? What is their function?(2). What are the intestinal villi? What is their structure, size, and function? How many in the small intestine?(3). Name some glands found in the small intestine, and the parts of it where each variety is most numerous. Where do the ducts of the liver and pancreas open?(4). What is the function of the large intestine? (5). How do plants and animals differ?(6). How do they resemble each other as regards the products of their tissues? What is the function of chlorophyll?(7). What are parasitic plants? How do they live? Name one found on the clover, hemp, and tobacco; the one causing fermentation; the one found on wheat, oats, and barley; the one on potatoes(8). What causes the manifestations of animal life?

Under what conditions do these changes take place? Describe some of them(9).

SECTION IV.

How may the foods of the body be classified?(1). Tell what you know of the organic nitrogenized principles(2). Where are substances of this class found? Name some of them(3). By what substances are the organic non-nitrogenized principles represented?(4). What is the origin of sugar? How does cane- differ from grape-sugar? What is glycogen? When is it formed, and where? Does sugar exist in the blood coming from the liver? When is it destroyed? What changes does it pass through in its destruction?(5). Can sugar be found in liver-substance during life? Why not? What produces the disease known as diabetes?(6). What is the source of starch? In what part of leaves is it formed? Describe its changes in the nutrition of the plant. Name some plants in which starch is found as a food(7). Give the size of starch-grains. Of how many parts is a starch-grain composed? What are they called? Which is the part acted upon by the saliva and colored blue by the addition of iodine?(8). What is the appearance of starch-grains under the microscope? What causes this appearance?(9). Name some of the properties of starch(10). What is the origin of fat? In what climate is it most extensively used as an article of food? In what form is it taken?(11). Name some animal fats. What is butter? What produces the rancid taste of butter? (12). Name some plants that yield fat? Where is the tallow tree found? What part produces the fat? For what is it used?(13). Are fats true hydrocarbons? Why not? Where are they found? Is fat formed in the body? Is it laid up as reserve matter? What becomes of it during hibernation and starvation? Is sugar or starch ever laid up in the body?(14). Is fat discharged from the body in health? What is the function of fat in the economy? Will it, as a single article of diet, support life?(15). What is the origin of the inorganic principles? Name some of them, and tell their condition of existence in the body(16). What important salts are found in the teeth and bones? What part of the body does water form? Is iron essential to health? Where is it normally found as an article of food?(17).

SECTION V.

Is milk an important article of food? Why? Give the composition of cow's milk(1). How is butter obtained from milk?(2). How

and where are milk-globules formed? What is their size? Have they an investing membrane? What is it called? What is the milk-plasma? What produces the opacity of milk?(3). How does human differ from cow's milk when treated with ether?(4). Does true butter contain any casein? How much? Is it ever adulterated? With what? What is oleomargarine? From what is it made, and by whom was it devised? What is butterine? How is it made? Is the name used now? What name is used to include all artificial butters? How may adulterations be detected? Is pure butter ever white? Under what condition may crystals appear in pure butter?(5). What is casein? How is it kept in solution? What causes its spontaneous coagulation? How does the casein of cow's milk behave when acted upon by human gastric juice?(6). How does casein differ from albumen? How is it affected by rennet?(7). What is cheese? How is it made? How much fat do the different varieties of cheese contain?(8). What is the specific gravity and reaction of milk?(9). Tell what you know of diseases that may be caused and disseminated by the milk-supply(10). Name a milk-poison that may be found in cheese, and sometimes in ice-cream(11). What is the composition of butter?(12). What is the composition of cheese?(13). What can you say of bread as an article of diet? Name some principles found in it(14). Why should bread contain numerous little air-spaces?(15). What is used to render the dough porous? How is it generated?(16, 17). Write the composition of bread(18). What can you say of oats as an article of food? In what form is it generally used? Is it ever made into bread? Why not? What is the composition of oatmeal?(19). Is rice an important article of food? How should it be prepared? Are the starch-grains large or small, single or compound? Name some varieties of rice. Write its composition(20). What do you know of Indian corn as an article of diet? What is its composition?(21). Does the use of Indian corn ever produce disease?(22). Why are beans and peas important articles of food? Write the composition of peas(23). Tell what you know of the potato as an article of food. What disease occurring among sailors and soldiers is relieved by its use?(24). Where is the sweet-potato most extensively used?(25). Write the composition of the common potato?(26). Tell what you know of meat as an article of food(27). Is disease ever caused by eating imperfectly-cooked meat? Tell what you know of the cause and symptoms of trichinosis(28). Tell what you know of the tapeworm and its cause(29). How should meat be cooked? Is chicken-broth as nutritious as that of other meats?

(30). Write the composition of beefsteak, roast or boiled meat, salt pork, smoked ham, poultry, Chicago corned beef(31). Are eggs important as articles of food? What do they contain? What is the weight of an ordinary egg? How much is shell?(32). Write the composition of egg, yelk and white(33). Is alcohol a food? What is it? What is its action on the tissues? Is this normal?(34). Is alcohol ever formed in the blood? from what? What becomes of it? What does it produce? Is the use of alcohol ever beneficial in conditions of disease? Why? Is alcohol necessary when there is sufficient food? Is it injurious? Why? When should it be taken, if taken at all?(35). What becomes of alcohol when small quantities are taken? When large quantities are taken? To what is the odor of the breath of an alcoholic due?(36). Name some beverages containing alcohol. How is that found in beer and wine formed?(37). What is sweet wine? What gives the peculiar odor and flavor to wines? How is the fusel oil of brandy separated from the alcohol? (38). Name some of the beverages and the quantity of alcohol they contain. What is the effect produced on the tissues by the use of beer? (39). What is the observation of nearly all persons with reference to the use of alcohol in any form?(40). Write upon the blackboard the table showing the chances of life in the temperate and intemperate(41). What is the average duration of life after commencing the use of alcohols in mechanics, merchants, professional men, females?(42). Is the death-rate increased or diminished by using more than one kind of alcoholic beverage?(43). What do you know of the history of alcoholic beverages?(44). What do you know of the yeast-plant? When was it first seen?(45).

SECTION VI.

Name the digestive fluids(1). What is the saliva? Where is it found? What does it contain?(2). Describe the parotid saliva(3). Describe the submaxillary saliva(4). Describe the sublingual gland (5). Describe the sublingual saliva(6). Name some causes of the variation of flow from the different glands(7). Describe the mixed saliva, its specific gravity, quantity, reaction(8). What is ptyalin? What is its function? Is it present in the saliva of newborn children? (9). Name some substances that increase the flow of saliva; some that diminish the flow(10). Describe the function of the parotid saliva(11). What is the function of the mixed saliva? Will it act upon starch in the cavity of the stomach?(12). Name some substances that increase

the activity of the saliva; some that diminish its action. Does tea favor digestion? Why?(13). Upon what alimentary principles does the saliva act? Do organisms exist in the alimentary canal in great numbers? Have any been secured and their action studied? By whom?(14). Tell what you know of the secretion of gastric juice; its quantity, specific gravity, reaction, odor, and taste. What gives it its digestive properties?(15). What must true gastric juice contain? What is the acid of the gastric juice? Will it act with any other acid?(16). Describe the appearance and behavior of the gastric mucous membrane upon the introduction of food(17). Under what conditions may the gastric juice be rendered inactive? Does it ever cease to be formed? When?(18). How is gastric digestion affected by wine, tea, coffee, large and small doses of brandy, rum, or whiskey?(19). Name some vegetable substances that will facilitate gastric digestion(20). Name some peculiar properties of gastric juice(21). Describe the action of the gastric juice on starch(22). Describe the action of the gastric juice on the sugars(23). What is the action of the gastric juice upon fats? (24). Is the action of this fluid on the nitrogenized principles important?(25). What is the action of the gastric juice on meat?(26). What is its action on the proteids? What is peculiar about the action of pepsin?(27). Describe the action of the gastric juice on casein as found in cheese and milk(28). What is its action on albumen in all forms taken?(29). Describe albumen(30). Describe peptones. How is pepsin influenced by alcohol?(31). What is the duration of stomach digestion? Describe the movements of the stomach during the digestive act(32). What becomes of the gastric juice that remains after the food is supplied? How is the mucous membrane of the stomach protected from the action of the gastric juice?(33). Into what part of the duodenum is the bile discharged? Describe it(34). Tell what you know of the function of the bile in digestion(35). What quantity is secreted in twenty-four hours? Name some of its functions(36). Is bile essential to life? How can this be shown?(37). What causes the progressive emaciation in animals with a biliary fistula?(38). What is cholesterin? Where is it found? By whom and when was it first described? What is stercorin?(39). Describe the glycogenic function of the liver(40). What is the size of the liver-cells? Are they important structures?(41). Where is the pancreatic juice formed? Describe the pancreas. How many ducts has it? Where do they open? (42). Describe the pancreatic juice. What is its active principle called? Is it a simple substance?(43). What is its action on starches

and cane-sugar? To what ferment is it due?(44). What is the action of the pancreatic juice on albuminoids? To what ferment is this action due? What increases its action?(45). What is the action of the pancreatic juice on fats? What is the ferment? Is the pancreatic juice essential to life? Is the action of the pancreas continuous?(46). Describe the intestinal juice and its action on the different alimentary principles(47). What is the function of the large intestine?(48).

CHAPTER XI.

SENSE-ORGANS AND SPECIAL SENSES.

SECTION I.

1. The **special senses** may be classified as follows: *olfaction*, or the sense of smell; *gustation*, or the sense of taste; *vision*, the sense of sight; *audition*, the sense of hearing; and the special sense of touch, of which there are several modifications—that of pressure or resistance, heat, cold, etc.

2. The **organs of sense** are the true sources of all mental life. Without them it would be impossible to arrive at a knowledge of things external. Active cerebration in the absence of all the senses is a doubtful possibility. The beauties of land and sea and sky never appear to the blind, though their souls may be filled and satisfied as Nature speaks to them of her gentleness and power through the fragrant perfumes of her painted bosom and the sweet music of her myriad choristers.

3. Nowhere in the whole economy of the human body is there encountered such delicate, elaborate, complex, and efficient structure as in the anatomy of the organs of special sense. Each part seems to be arranged with special reference to every other part, and all in

harmonious action in the performance of some definite function.

4. **Olfaction, or the Special Sense of Smell.**—The organ of smell is the mucous membrane covering the olfactory region of the nasal cavities. This region receives the distribution of the olfactory or first cranial nerve, which is the nerve of smell, and varies in extent with the distribution of that nerve.

5. The olfactory mucous membrane covers the upper part of the lateral boundaries of the nasal cavities and the corresponding part of the septum on each side, extending over the superior and part of the middle turbinated bones. It differs from the mucous membrane lining the remainder of the nasal cavities in being thicker, in containing tubular glands, and in being covered by a single layer of branched, elongated epithelial cells containing a coloring matter or pigment which gives to the parts a reddish-yellow or brownish color.

6. The lining membrane of the nose, or the Schneiderian mucous membrane, is continuous with the mucous membrane lining the throat or pharynx; with the opening conveying the tears from the eyes, the nasal duct, and the lachrymal canals; with the tube leading from the throat to the middle ear, called the Eustachian tube; with the large sinus within the superior maxillary bone, the antrum of Highmore; with the cavities within the body of the sphenoid and lateral masses of the ethmoid bone; with the ethmoidal and sphenoidal sinuses; and with the cavities between the plates of the frontal bone, the frontal sinuses.

7. The anterior nares open on the face in a direc-

tion outward and forward. The posterior nares open behind into the upper part of the throat or pharynx. The spaces between these openings are known as the nasal fossæ. The two nasal cavities are separate and distinct from each other. They are separated from the mouth below by the hard and soft palates.

8. The sense of smell is confined to the olfactory nerve, which is insensible to ordinary impressions. The fifth nerve gives common sensation to the lining membrane of the nose. Those substances capable of producing irritation of these cavities, such as the fumes of mineral and strong vegetable acids, as well as alkaline emanations, do so by directly influencing this nerve.

9. The superficial origin of the olfactory nerve is by three roots from the median side of the inferior surface of the frontal lobe of the cerebrum. Two of these roots are white, and one—the middle—is gray. Their deep origin is still undetermined. The three roots unite to form a large nervous cord containing gray and white matter, after passing forward in a groove on the upper surface of the cribriform plate of the ethmoid bone. This cord swells into a bulb at the sides of the crista galli, and from the under surface of the bulb some sixteen to eighteen nerve-filaments descend through the openings in the cribriform plate of the ethmoid bone, which forms the roof of the nasal cavities. After reaching these cavities they are distributed to the mucous membrane of the olfactory region.

10. This region is supplied with the modified terminal endings of the olfactory nerves. These are called the *end-organs* or olfactory cells. They are elon-

gated and nucleated, and situated between the covering epithelium of the olfactory region, sending slender processes up between the epithelial cells to near the surface. The end of the olfactory cells opposite to that bearing the elongated filament is attached to the olfactory-nerve branches, which are here very irregular in outline and slender. Numerous cilia cover the mucous membrane over the region of smell in some animals (frog), being modified prolongations of the olfactory cells.

11. Numerous experiments result in pointing to the olfactory bulbs as the most important seat of the sense of smell. When these bulbs are diseased or destroyed, this sense is impaired or abolished, while in many of the inferior animals, characterized by the acuteness of this sense, the olfactory bulbs are correspondingly enlarged. This enlargement, however, is generally associated with a more extensive area of smell and an enlargement of the first bulb (*corpus album subrotundum*) of the optic thalamus, which is considered by some an olfactory centre communicating with the roots of the olfactory nerve through the tænia semicircularis, a translucent string of nervous matter located between the caudate nucleus and the optic thalamus, and communicating with the fornix anteriorly and the descending cornu of the lateral ventricle posteriorly.

12. The seat of our conscious perception of odors is probably located in the third and part of the middle convolutions of the temporal lobe of the cerebrum, near its apex. Diseases involving these parts may give rise to an excessively acute sense of smell (*hyperosmia*), or the sense may be purely subjective, as occurs in some

cases of hysteria and insanity, producing olfactory hallucinations. The complete abolition of the sense of smell (*anosmia*) may follow over-stimulation or destruction of this centre. Morphia has the power to diminish, and strychnia to increase, the acuteness of the olfactory sense. Alcohol at first increases and perverts the sense; later, it completely arrests it.

13. During the *inspiratory* act air laden with odorous gases or material emanations from odorous substances comes in contact with the olfactory cells in the mucous membrane of the region of smell. This is absolutely necessary for the production of olfactory impressions, and it seems necessary also that the odorous substances be carried to the nasal surfaces in a gaseous medium. Odorous liquids do not excite the sense of smell when brought in direct contact with the nasal mucous membrane.

14. An intimate relation exists between the sense of smell and that of taste. When the sense of smell is destroyed or impaired, the sense of taste is interfered with. The flavor of certain substances, as the aroma of coffee and roasted meats and the bouquet of wines, is only appreciated through the joint action of the organs of olfaction and gustation. The impression is probably first made on the organs of taste, and later on the organs of smell, by passing from the mouth through the posterior nares. Olfactory impressions, it is said, are not produced by the *exhalation* of air containing odorous materials. This is probably due to a tolerance of the mucous membrane, whereby it becomes accustomed to the impressions, as seems to be indicated in certain diseases of the stomach and the air-passages,

with the production of disagreeable and fetid odors which are not recognized by the person from whom they emanate.

15. The mere difference in the direction of the current of air would not seem sufficient to account for the blunted sensation in the person affected. When articles of food containing a disagreeable volatile substance, as onions, garlic, etc., are taken into the stomach, they give off emanations which, though unnoticed by the person eating them, are easily detected by others, provided they have not partaken of the same substance. In the latter case, neither party would be conscious of the peculiar odor caused by the exhalations of the other, although the odorous gases should pass over the nasal mucous membrane of both during the inspiratory act.

16. The sense of smell is absent in some aquatic animals (whale, porpoise). In fishes, reptiles, amphibians, and birds it is generally poorly developed. The sense is very acute in the shark and some carnivorous birds. It is best developed in the Carnivora and some of the Herbivora (deer).

SECTION II.

GUSTATION.

1. The **sense of taste** is confined to the mucous membrane covering the dorsal surface of the tongue, part of the soft palate and tonsils, together with the pillars of the fauces. The posterior part of the dorsum, the tip and margins of the tongue, have the gustatory

sense best developed, the middle part of the upper surface not being sensitive to gustatory impressions.

2. The **nerves of taste** are the chorda tympani and the glosso-pharyngeal, with the gustatory branch of the fifth cranial nerve.

3. The chorda tympani is from the facial nerve (probably from the intermediary nerve of Wrisberg). It joins the inferior maxillary division of the fifth nerve between the two pterygoid muscles, and passes to the tongue with the lingual branch of that nerve. This nerve is not endowed with general sensibility, but gives the sense of taste to the anterior two-thirds of the tongue.

4. The glosso-pharyngeal nerve gives the sense of taste to the posterior third of the tongue and is a nerve of common sensation as well, though the sensibility of the parts to which it is distributed is due mainly to the filaments of the fifth nerve.

5. The mucous membrane of the gustatory region, or region of taste, presents a number of small eminences called papillæ. Of these there are three varieties, two of which are intimately connected with gustation. They are called *fungiform*, *filiform*, and *circumvallate papillæ*.

6. The circumvallate papillæ number from eight to fifteen, and are limited to the posterior part of the dorsal surface of the tongue, where they are arranged in the shape of the letter V, with the point toward the pharynx.

7. The filiform papillæ are situated in greatest numbers near the margin of the tongue.

8. The fungiform papillæ are encountered all over the upper surface of the tongue, being more numerous

at the apex and lateral borders than in any other region.

9. The circumvallate papillæ are the same in structure as the fungiform variety, though much larger. Each bears a number of secondary papillæ, and is surrounded by an elevation, with a depression between such elevation and the papilla.

10. The fungiform papillæ also bear smaller papillæ, but are not surrounded by a ridge as are the circumvallate variety.

The gustatory organs are confined to the fungiform and the circumvallate papillæ, and the mucous membrane between the papillæ is insensible to gustatory impressions.

11. The true organs of taste are confined to the sides of the circumvallate and fungiform papillæ, and are in the form of elongated bulbs about twice as long as they are wide. Their transverse diameter is from $\frac{1}{600}$ to $\frac{1}{700}$ of an inch. They are composed of two kinds of cells. The outer or wall cells are elongated and spindle-shaped, and are arranged after the manner of the staves of a barrel, converging at the top in such a way as to leave a small opening called the *gustatory* or *taste-pore.* The inner cells are elongated and nucleated, presenting a hair-like prolongation from their upper end, which projects through the taste-pore, the lower end receiving the terminal filament of the nerves of taste. These cells are called the *gustatory cells*, or the *true cells of taste.*

12. Savory substances must be in a state of solution before they can be recognized and appreciated by the taste-organs.

13. There are a great variety of gustatory sensations, though they are all included by some authorities under saline, acid, sweet, and bitter. Flavor, as before stated, is the result of the joint exercise of the sense of smell and the sense of taste.

14. The demands of the system regulate and modify the taste to some extent, though it may be altered by age, climate, cultivation, or disease. The chorda tympani appreciates acids and salines, while the glosso-pharyngeal appreciates sweet, bitter, and alkaline impressions.

15. The centre of taste is located in the temporal lobe of the cerebrum. This sense sometimes becomes abnormally acute (*hyperguesia*) in the hysterical and insane, when they are able to detect the smallest quantity of savory substances in food. Diseased conditions of the temporal lobe, paralysis of the fifth nerve, injuries to, or tumors pressing on, the glosso-pharyngeal nerve, may be followed by loss or impairment of the sense of taste (*aguesia*), which may be general or confined to local areas.

QUESTIONS.

SECTION I.

Name the special senses and define each(1). How is mental life influenced by the special senses?(2). What is peculiar about the structure of the organs of special sense?(3). What is the organ of smell? (4). Where is the olfactory mucous membrane?(5). With what other membranes is it continuous?(6). What can you say of the nasal cavities?(7). What nerve gives general sensibility to the lining of the nose?(8). Give the origin, course, and distribution of the olfactory nerve(9). What are the olfactory cells?(10). Where is the seat of smell located?(11). Where is the centre for the conscious perception

of odors?(12). In what condition must substances be to excite olfactory impressions?(13). Is there any relation between the sense of smell and that of taste?(14). Does difference in the direction of the air-current modify the energy of olfactory impressions?(15). Is the sense of smell absent in any animals?(16).

SECTION II.

What is the organ of taste?(1). Name the nerves of taste(2). What is the origin and properties of the chorda tympani?(3). What part of the tongue is supplied by the glosso-pharyngeal nerve?(4). How many varieties of papillæ on the tongue?(5). Where is each situated?(6, 7, 8). Describe the circumvallate and fungiform varieties (9, 10). Describe the true organs of taste, and tell where they are found(11). What must be the condition of substances before they can create savory impressions?(12). How many kinds of gustatory sensations are there? What is flavor?(13). What regulates the sense of taste? By what nerve are acids appreciated?(14). Where is the centre of taste?(15).

CHAPTER XII.

VISION.

SECTION I.

1. The conscious perception of light is called *sight*. It depends upon the power of certain nerve-terminations to transmit influences, produced by regular ether-waves or luminous vibrations, to the optic nerve, the fibres of which conduct the stimulus to the brain, where it is recognized as light.

2. The only representative of eyes in the lowest animals is a mass of colored or pigmented protoplasm called an *eye-speck* or eye-spot. Eyes of this character have no special nerve-endings in them, and are sensitive only to heat, the rays of which are absorbed by the pigment of the sensitive protoplasm.

3. Many inferior members of the animal kingdom have no sight-organs at all; as, for example, many of the endo-parasite, intestinal worms, protozoa, cave-fishes, and certain of the mollusks.

4. For the production and perception of images from lighted objects it is necessary that there should be not only an optic nerve to convey impressions to an appreciating centre in the brain, but an apparatus containing refractive and recording media in front of the modified expansion of this nerve as well.

5. The highest type of eye is found in the verte-

Fig. 67.



THE EYE, RIGHT SIDE.

1, frontal bone; 2, 4, muscles; 5, 5, 5, the sclera or white protecting tunic of the eye; 6, 6, 6, 6, iris or curtain, which regulates the quantity of light going to the refractive media of the eye during the act of vision; 3, lachrymal or tear gland.

brata. As it exists in man it is formed of the termination of the optic nerve in a delicate nervous membrane called the *retina*, partly surrounding the refractive media and covered by vascular and protecting sheaths.

6. The **human eye** is nearly globular in shape, with a little greater antero-posterior than vertical or transverse diameter. In old age all the diameters become more nearly equal. The different diameters of the eye proper are a little under one inch.

7. The eye is situated in the cavity of the bony orbit (which is a pyramidal-shaped depression with its apex inward and backward, corresponding to the entrance of the optic nerve and its base opening at the upper and anterior part of the face), resting upon and partly surrounded by a mass of fat, protected in front by the eyelids, and moved by muscles which are inserted into its white coat.

8. The **second** or **optic nerve** is called the *nerve of sight.* It arises from the brain (tubercula quadrigemina) by two roots, which unite to form a band of nervous matter called the *optic tract.* As these nerves run from their origin in the brain to the eye, they present a peculiar arrangement of their fibres and receive different names in different parts of their course.

9. Some of the fibres decussate or cross at the anterior part of the superior surface of the sphenoid bone in the optic groove, anterior to the olivary process. This is called the *optic chiasm* or *optic commissure.* That part of the nerve posterior to this is called the *optic tract;* the part extending from this to the eyeball is called the *optic nerve.*

10. The nerve-fibres forming the chiasm take as many as four directions. On its anterior part fibres are seen passing from one eye to the other without running back to the optic tract and brain. On its posterior part are fibres, not always present, extending from one side to the other, uniting the optic tracts, but not passing through the chiasm to the optic nerves. Laterally are fibres passing from one optic tract to the optic nerve and eye on the same side, and nearer the middle of the chiasm are encountered nerve-fibres which cross in both ways from the optic tract on one side to the optic nerve and eye of the opposite side. These are the true decussating fibres.

11. Nerves from the left side of the brain pass through the chiasm and supply the nasal or inner half of the retina of the right eye, other fibres passing to the outer or temporal half of the retina of the left eye. This distribution is shown in certain forms of impaired vision. When the fibres of the optic tract on one side become affected or destroyed by disease or pressed upon by growths within the cranium, there is loss of vision in the temporal half of the retina of the same side and the nasal half of the retina of the opposite side. This affection is called *homonymous hemianopsia* (half vision in each eye), and may indicate a lesion behind the optic tract or in the occipital lobe of the cerebrum, which is now considered to be the centre of sight.

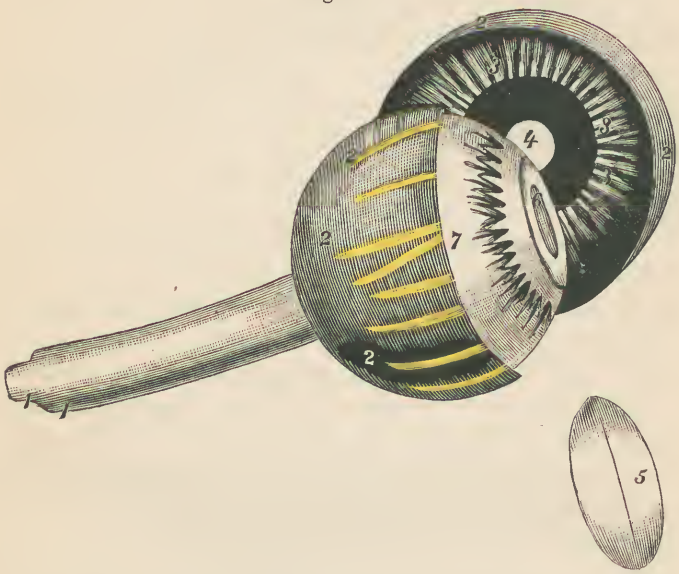
12. If there be pressure upon or destruction of the chiasm, especially anteriorly, there is loss of vision in the nasal half of each retina, and a binasal hemianopsia is produced.

13. The optic nerve and retina are insensible to

ordinary impression, and when irritated or stimulated do not occasion pain. They are concerned in the analysis of luminous vibrations in the production of sight.

14. The optic nerve penetrates the coats of the eye, and forms a little elevation where it enters the retina,

Fig. 68.



Eye, showing 1, 1, the optic nerve; 2, 2, 2, 2, 2, choroid with the ciliary nerves; 3, 3, 3, ciliary processes; 4, opening in the iris called the pupil, sometimes called the sight; 5, lens removed; 6, normal position of the crystalline lens in its capsule; 7, retina, exposed by cutting away the choroid.

which is not exactly in the centre of the antero-posterior axis of the eyeball, but about one-twelfth of an inch below and one-eighth of an inch to the nasal side of the central point.

15. The external coat of the eyeball is called the

sclerotic (hard), or "white of the eye." It is composed of dense fibrous connective tissue, with some elastic fibres, and surrounds the posterior five-sixths of the globe of the eye. Where the optic nerve penetrates the eyeball behind, this coat is thinned and aids in forming the lamina cribrosa (sieve membrane), through the openings of which the nerve-fibres of the optic nerve reach the retina.

16. The anterior one-sixth of the sclerotic coat is greatly modified, and is transparent. This is called the *cornea*, and is the most prominent segment of the eye-globe. This, with the sclerotic, really forms the first coat of the eye.

17. The next coat is called the *choroid*. It is composed of blood-vessels, loose connective tissue, and pigment-cells. The inner layer of this coat lies next to the layer of rods and cones of the retina.

18. This coat is connected in front with the iris and ciliary muscle, terminating in the ciliary processes, which are folds projecting inward toward the crystalline lens. They number from sixty to eighty, and are of two sizes, large and small. The larger ones number from forty to sixty, and alternate irregularly with the smaller ones. These folds of the choroid receive folds of the anterior layer of the hyaloid membrane, which becomes continuous with the anterior layer of the capsule of the crystalline lens. This folded part of the capsule of the vitreous humor is called the *zone of Zinn*.

19. The **ciliary muscle**, sometimes called the ciliary ligament, is attached in front to the junction of the cornea and sclerotic and to the posterior part of the cornea, called *Decement's membrane*, and to that part of

it which extends from the circumference of the cornea to the anterior surface of the iris (*ligamentum iridis pectinatum*). Behind it is continuous with the choroid. During its contraction it compresses the contents of the hyaloid membrane and relaxes the suspensory ligament of the lens. It regulates the changes in the lens for accommodation of the eye to vision for near and distant objects.

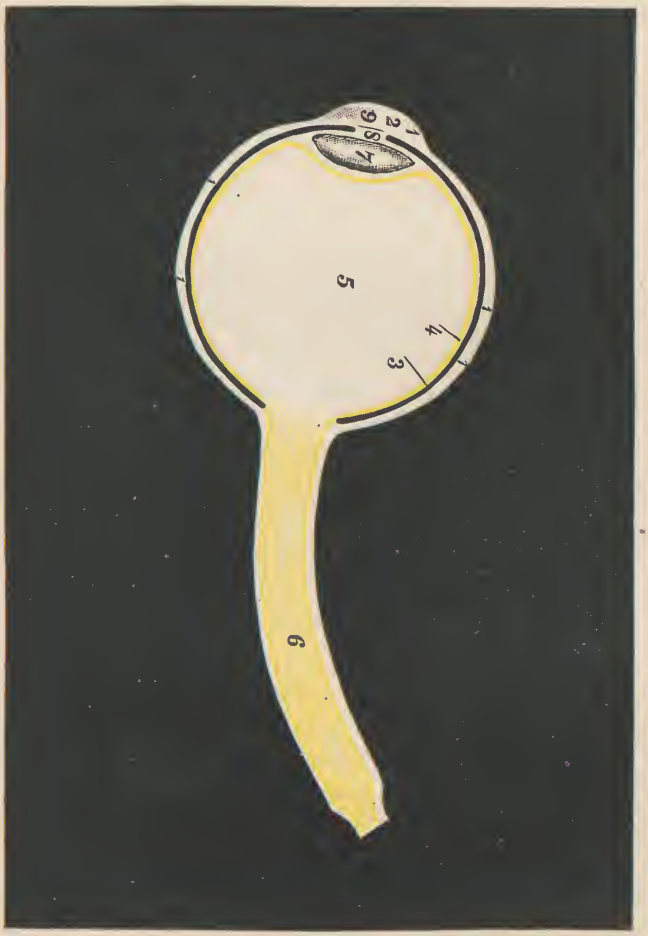
20. The **iris** is a muscular curtain or diaphragm suspended in the aqueous chamber of the eye in front of the crystalline lens. It is attached by its circumference to the sclero-corneal junction, and is properly a prolongation of the choroid in front of the lens.

21. The function of the iris is to regulate the quantity of light entering the eye and to cut off the peripheral rays. Light enters the iris through a round hole a little to the nasal side of its centre, called the *pupil*, the size of which is regulated by the muscular fibres of this rainbow curtain.

22. The muscular fibres of the iris are arranged as a circular band around the border of the pupil, contraction of which diminishes the diameters of this opening. Radiating from the pupil to the circumference of the iris are other non-striated muscular fibres, contraction of which increases all its diameters.

23. The **retina** is the next layer, internal to the choroid, and is called the *third layer* of the eyeball. It is the only layer directly concerned with the sense of sight. Its extent is nearly defined by the limitations of the choroid. It extends over the posterior part of the hyaloid membrane, and nearly as far forward as the ciliary processes, where it seeks an attachment to

Fig. 69.



VERTICAL SECTION THROUGH THE EYE AND OPTIC NERVE,

1, sclerotic coat; 2, its anterior part, the cornea; 3, choroid; 4, retina; 5, cavity filled with vitreous humor; 6, optic nerve; 7, crystalline lens; 8, posterior chamber; 9, anterior chamber.

the zone of Zinn by a finely serrated edge called the *ora serrata.*

24. About one-twelfth of an inch to the temporal side of the point of penetration of the optic nerve is a yellow spot, called the *yellow spot of Sömmering*, or *macula lutea.* In the centre of this is a depression (*fovea centralis*) directly in the axis of vision, striking an angle, however, with the mathematical axis of the eye. The *macula lutea* (yellow spot) has its long axis transversely, which measures one-eighth of an inch, while its vertical diameter measures about one-thirty-sixth of an inch.

25. The retina has as many as nine or ten layers, but the most important ones are the layer of rods and cones, the layer of nerve-cells, and the pigmentary layer. These are the only layers directly concerned in receiving impressions of light.

26. The rods are absent at the macula lutea and fovea centralis, this layer being represented here by the cones alone.

27. Lying beneath the retina is the **hyaloid membrane,** surrounding the vitreous humor of the eye, which fills and occupies nearly its posterior two-thirds. This membrane becomes continuous in front with the suspensory ligament of the crystalline lens.

28. The **aqueous chamber** of the eye is bounded behind by the anterior surface of the crystalline lens, and in front by the posterior surface of the cornea. This space contains the aqueous humor, and is divided by the iris into *chambers* which communicate with each other through the pupil. The **anterior chamber** is limited in front by the posterior surface of the cornea, behind by the anterior surface of the iris. The **pos-**

terior chamber is limited behind by the lens, in front by the posterior surface of the iris, and is much smaller than the anterior chamber. The posterior surface of the iris is in contact with the lens, except at the centre and near the periphery.

29. The crystalline lens in the invertebrates is a part of the cornea (the cornea forming the image in many cases for the sensitive crystalline cone beneath). In aquatic vertebrates it is globular or nearly round. In the human subject it is biconvex, with the greatest convexity behind. It is situated in a depression in the anterior part of the vitreous humor called the *hyaloid fossa*, which is lined by a part of the hyaloid membrane. Early in life the convexities of the lens are well marked; later in life they diminish and the lens becomes harder. It measures in adult life one-third of an inch in its transverse, and one-fourth of an inch in its antero-posterior, diameter.

30. When the hyaloid membrane reaches the anterior limit of the vitreous humor and the termination of the retina, it divides into two main layers. One of these lines the cavity receiving the lens, and the other divides when it reaches the border of the lens into two layers, which become continuous respectively with the anterior and posterior layers of the lens capsule. These layers of the hyaloid membrane constitute the suspensory ligament of the lens, and where they divide they present a space called the *canal of Petit.*

31. The human eye has been likened to a camera obscura, the iris representing the *diaphragm*, the crystalline lens the *lens*, and the retina the *ground-glass plate*

which receives the inverted image, while the colored choroid absorbs the superfluous light which would blur the picture.

32. When rays of light fall on the cornea and pass through the crystalline lens, they are brought to a focus on the retina. They cross each other, however, before they are focused, hence the image on the retina is inverted. The accommodating power of the eyes, by increasing and diminishing the curvatures of the lens, insures (within certain limits) the proper focus of rays of light coming from near or distant objects upon the surface of the retina.

33. When the antero-posterior diameter of the eye-globe is too long it is called a *myopic* (nearsighted) *eye.* In eyes of this kind the image is brought to a focus anterior to the retina, so that objects to be seen must be brought very close to the eye, when the rays of light proceeding from it will be more divergent and brought to a focus farther back; muscular effort cannot correct an eye of this kind, and there is not the same strain in viewing objects at a distance as in the case of farsighted eyes. Glasses with concave lenses will prove of benefit to such eyes, by causing the light from distant objects to become more divergent before passing through the lens. Myopic children generally prefer study and in-door occupations to out-of-door exercises, because they have no difficulty in seeing near objects.

34. When the antero-posterior diameter of the eye is too short, the rays of light will be focused too late, and the image be produced too far back, behind the retina. Glasses with convex lenses will benefit such an eye by converging the rays of light before they pass

through the lens, bringing the focal points and the image farther front on the retina.

35. The eye is the most active of all the organs of special sense. It is constantly taking pictures of external objects—unconsciously, perhaps—during the waking moments. It acts without conscious muscular effort on all objects at a distance of more than twenty feet away when its diameters are in natural harmony with the refractive power of its media, and hence can remain passive or in a condition of rest a greater part of the time.

36. An eye with its antero-posterior diameter too short (hypermetropic or farsighted eye) is never in a passive state, as it requires a special muscular effort to focus every object seen. It must work incessantly during the waking hours, and rest for such an eye comes only with sleep or when it is voluntarily covered by the lids. Eyes of this kind should receive early attention, as they are productive of dizziness, sick or nervous headache, and many obscure nervous troubles. Children suffering with hypermetropia prefer out-of-door exercises and may boast of acute vision.

37. The eyes are covered and protected in front by the lids, which are lined with a mucous membrane called the *conjunctiva*. This also covers the anterior part of the globe, and is continuous with the lining membrane of the canals and ducts leading from the inner part of the eyes to the inferior meatus of the nose.

38. The anterior surface of the eye is bathed and kept moist by the tears which are secreted by the lachrymal gland, an almond-shaped body lodged in a

depression at the upper and outer part of the angle of the orbit. It resembles the salivary glands in its structure, and pours its secretion (tears) over the anterior surface of the eye through six or seven small ducts which open on the upper and outer part of the conjunctiva.

39. With the motion of the lids (especially the upper) the tears are washed over the cornea, and clean it from all particles of dust and keep it moist. They pass to the inner canthus of the eye, where they enter the *puncta lachrymalia* (little openings on the summit of the papilla lachrymalis which lead into the lachrymal canals), which can be seen by drawing down the inner part of the eyelid. The puncta lachrymalia, one for each lid, upper and lower, open into the lachrymal canals, which run together at the lachrymal sac. This is the upper enlarged or dilated part of the nasal duct, which conveys the tears to the inferior meatus of the nose. Obstruction of any part of this tube will cause the tears to overflow on the cheeks (epiphora).

40. The eyebrows protect the eyes from perspiration, while the cilia or eyelashes guard against the entrance of foreign bodies. The Meibomian glands can be seen as a number of white strings between the cartilages (tarsal) of the eye and the conjunctiva on everting the lids. They secrete an oily substance which moistens the edges of the lids and aids in preventing the overflow of tears under normal conditions.

41. The pigment-layer of the retina, or retinal epithelium, has the power to form a substance called *visual purple*, which is found in the outer segments of the rods and is probably decomposed in the act of vision. It

does not exist in the cones (except in the eyes of certain birds, fishes, and reptiles), and is not found in the fovea centralis of the mammalian eye—a fact which has led to the belief that it is not directly essential to vision. It is formed during darkness, and renders the retina very sensitive to light. When the retina has been exposed to the actinic rays for a variable time the visual purple is changed to the visual yellow, a condition which seems necessary for the proper functions of the retina under strong illumination.

42. The inability to see distinctly after suddenly passing from darkness into a brilliantly lighted room, or from a darkened room into the bright sunlight, is due to the hypersensitiveness of the retina occasioned by the great accumulation of visual purple, the normal condition returning gradually as the retina is bleached and visual yellow is formed.

43. The difficulty in seeing clearly on going suddenly into the dark from a bright light is due to the absence of the visual purple. This gradually replaces the visual yellow, and the power of vision is partly restored.

44. The eyes of many nocturnal animals (bat, owl) and some fishes (skate) contain no cones, but are supplied with an abundance of rods and visual purple, while many diurnal birds have an abundance of cones and few rods.

45. External objects are generally seen by both eyes at the same time. In many fishes the eyes are so placed that each one sees objects not seen at the same time by the other.

The eyes of insects are very complicated, and are

generally of two kinds, simple and compound. Examples of the simple eye may be seen in mollusks, annelids, insects, bees, and locusts. Where they generally occur on the top of the head in the form of a triangle, they are three in number and are called *ocelli* (little eyes). Their essential parts are a cornea, covering a crystalline lens in the shape of a cone, which reaches to certain modified cells in the hypodermal layer of the skin. In this are found nerve-terminations corresponding to the retina, and which are continuous with the optic nerve. The vertebrate eye is but the perfection of this type.

46. The compound eyes ("facetted eyes") generally exist in single pairs. They are not composed of a simple eye, but are a complicated single eye. They may be seen on insects and crustacea. They are very prominent, and have a mosaic appearance due to the facets or cornea, which vary in number from fifty in the ant to as many as twenty-eight thousand in the dragon-fly. The house-fly has four thousand. These facts may easily be seen by examining the eye of a wasp with the aid of a simple hand lens.

47. The excessive use of alcohol and tobacco is one of the most potent causes of functional diseases of the optic nerve and retina, producing impaired vision and complete blindness (amblyopia and amaurosis).

Directions for Dissecting an Eye.—A better knowledge of different parts of the eye may be obtained by dissecting the eyes of different animals than by any amount of reading. The eye of the cat or rabbit is easily obtained, and presents all the parts well developed and large enough to be handled with con-

venience. The only instruments that are necessary are a small pair of sharp-pointed scissors, a pair of delicate forceps, a needle mounted in a holder, a slender, sharp-pointed knife, and a small saw or strong pair of bone-forceps. With these good dissections of all the main parts of the eye can be made.

To expose the muscles saw or cut through the bone on each side above the eye. With a slight stroke the piece can be broken from its attachments, exposing from behind a white membrane (periosteum) and a mass of fat. Cut the membrane away and carefully remove the fat. The muscles are now exposed as fleshy tendinous bands running from behind forward to be inserted into the globe of the eye a little behind the cornea. They are six in number—superior and inferior oblique, superior, inferior, internal, and external recti. Each one should be carefully cleaned and its action demonstrated by passing a hook beneath it and pulling, when it will cause the globe of the eye to move. Any position of the eyeball which relaxes the muscles (makes them hang loose) indicates the direction of the action of that muscle during life. The muscles are inserted as their names indicate. The tendon of the superior oblique passes through a groove or pulley near the edge of the bone, and is then reflected outward for attachment.

The insertion of the muscles may next be divided close to the globe, when a delicate skin-like membrane (conjunctiva) will be seen reflected from the globe to line the inner surface of the eyelids. This may be trimmed away, and the optic nerve divided behind, when the eyeball will be set free.

If the globe is not distended and full, it may be inflated with air by introducing a delicate blowpipe through the optic nerve and filling the cavity of the vitreous humor. As the pipe is withdrawn a ligature must be tied tightly around the optic nerve.

The eye should now be pinned to a piece of soft pine board or shingle with the cornea looking up, or a better plan is to procure an ordinary pie-pan with sloping sides to admit plenty of light. The bottom of this should be covered with a layer of melted beeswax. After the wax has hardened a part of it near the centre may be softened by touching it with a heated piece of iron, and while still soft the eye should be pushed down into it, the cornea up, and allowed to remain until the wax hardens around it and holds it securely. If desired, the pan may be nearly filled with water (not covering the entire eyeball), which aids very much by keeping all the parts moist. The knife is now pushed through the cornea close to its attachment to the sclerotic. The aqueous humor will then escape. With the scissors cut the cornea away, following its circumference. This will expose the anterior surface of the iris, which can be made prominent by pressing on the globe. In the centre is the pupil, vertically oval in cats. Cut the iris away, beginning at the margin of the pupil and extending to the circumference, which is followed around. Note the color of both faces of this curtain.

The lens now comes into view. Make a delicate cut across its anterior surface in two directions at right angles with each other. This divides the anterior layer of the capsule of the lens, when by pressure at the sides and a little assistance with the needle the lens is forced

from its cavity. Its anterior and posterior surfaces should be examined, and it should then be put on a piece of newspaper and the letters examined through it. The torn part of the capsule should now be pulled upward with the forceps, which will separate the anterior part of the hyaloid membrane from the overlying coats, and partly also the ciliary processes from the zone of Zinn, and loosen the anterior attachments of the retina (*ora serrata*). The scissors should next be introduced at the anterior margin of the sclerotic, where the cornea has been cut away, and the sclerotic and choroid divided for a distance of one-quarter of an inch backward; then, turning at right angles, divide both structures around the entire circumference. To this band will be attached the ciliary processes.

The vitreous humor should next be evacuated, when the retina will be exposed. Before the vitreous humor is discharged the optic nerve may be seen at the fundus of the eye by looking directly down. It expands into the nearly transparent retina, through which may be seen the inner layer of the choroid which gives the peculiar color to the cat's eye in the dark. This layer is sometimes called the *tapetum* (carpet) or *tapetum nigrum*. The outer white coat is the sclerotic. After this is removed, by careful dissection the external coat of the choroid is brought into view. As each part is separated it should be drawn to one side of the pan for more careful examination after the main dissection is completed.

QUESTIONS.

SECTION I.

What is sight? Upon what does it depend?(1). What kind of eyes have the lowest animals? Have they special nerve-endings in them? (2). Name some animals having no organs of vision(3). What is necessary for the production of an image?(4). In what animals is the highest type of eye found?(5). What is the shape of the human eye? (6). Where is the eye situated? How surrounded?(7). What is the nerve of sight called?(8). Name the different divisions of it(9, 10, 11). What produces binasal hemianopsia?(12). Are the retina and optic nerve sensible to ordinary impressions?(13). Where does the optic nerve penetrate the retina?(14). What is the sclerotic?(15). What is the cornea?(16). What is the choroid?(17, 18). Describe the ciliary muscle(19). What and where is the iris?(20, 21). What modifies the size of the pupil?(22). Describe the retina(23). Where is the macula lutea?(24). How many layers has the retina?(25). What part is found at the macula lutea?(26). Where is the hyaloid membrane?(27). Bound the chambers of the eye(28). What is the size and shape of the crystalline lens?(29). Describe the capsule of the lens(30). To what instrument used by the photographer has the eye been likened? Why?(31). Why is the image on the retina inverted? (32). What condition of the eye produces nearsightedness (myopia)? (33). What causes hypermetropia (farsightedness)?(34). Does the eye ever rest while awake?(35). Is the farsighted eye ever passive during waking moments? Why not?(36). What is the conjunctiva? (37). What is the lachrymal gland?(38). How are the tears carried to the nose?(39). Where are the Meibomian glands? What is their function?(40). What forms the visual purple?(41). Why are the eyes dazzled in passing into a bright light?(42). Why is vision indistinct when first entering the dark?(43). Are rods and cones present in the eyes of all animals?(44). What kinds of eyes have insects?(45). What is peculiar about the compound eye? How many faces may it have?(46). How does the excessive use of alcohol and opium affect the eyes?(47).

CHAPTER XIII.

AUDITION, OR HEARING.

SECTION I.

1. The **ear** is the organ of hearing. The fully-developed ear in the human being is composed of two principal parts, one for the conveyance or transmission of sonorous vibrations, the other for the production of auditory sensations, which become conscious impressions when conducted to the centre of hearing in the brain.

2. That part of the auditory apparatus which conducts sound is divided into the *external* and the *middle ear*. The former collects and conveys sounds to the latter, which modifies and transmits them to the internal ear—the true organ of hearing.

3. In mammals the **outer ear** begins with a corrugated expansion of cartilage and skin, called auricle or pinna or ear-shell. Leading from this, in a direction forward, downward, and inward, is a tube or outer ear-canal about one inch in length, reaching to the cavity of the middle ear, from which it is separated by the ear-drum or tympanum (membrana tympani). This membrane is oval in form, being a little longer in its vertical than in its antero-posterior diameter. It is

placed at an angle, and does not stand vertically between the middle and external ears. Viewed from the external ear, it presents a depression, while a corresponding convexity looks toward the cavity of the middle ear.

4. The **middle ear** is a cavity within the substance of the petrous portion of the temporal bone. It communicates with the cavity of the mouth by the Eustachian tube, which opens into the upper part of the pharynx behind the posterior nares; with the vestibule and cochlea of the internal ear by the fenestra ovalis and the fenestra rotunda; and with the mastoid cells by several openings on its posterior wall.

5. This cavity contains a chain of small delicate bones extending from the tympanum to the internal ear. They are three in number in man—*malleus, incus,* and *stapes* (hammer, anvil, and stirrup). The malleus is most external, and is attached by its handle to the membrana tympani; the incus is between the malleus and stapes; the stapes is the most internal bonelet, and touches with its base the membranous internal ear at the fenestra ovalis, which is closed by it and the annular ligament holding it in position.

6. A little muscle is attached to the handle of the malleus (tensor tympani), which when it acts draws it inward and produces tension of the membrana tympani. Another muscle (stapedius) is attached to the head of the stapes, contraction of which draws the head backward and relaxes the ear-drum. These belong to the sound-conducting division of the ear.

7. The **internal ear** lies within the petrous portion of the temporal bone. It receives the waves of sound

and produces the sensation of hearing. It is sometimes called the *auditory labyrinth.* This true labyrinth is membranous, and is surrounded by an osseous labyrinth of the same shape.

8. The membranous labyrinth is composed of two parts or sacs. The larger of these is situated above

Fig. 70.



EXTERNAL, MIDDLE, AND INTERNAL EAR.

1, 1, 1, cochlea; 2, 2, 2, semicircular canals; 3, 3, 3, bone; 4, 4, 4, pinna; 5, 5, meatus auditorius externus; 6, 6, 6, 6, membrana tympani, or ear-drum; 7, musculus tensor tympani; 8, Eustachian tube; 9, middle ear, or cavity of the tympanum; 10, stapes, malleus, and incus, the three bones or ossicles of the ear; 11, part of the parotid gland.

and posteriorly, and communicates with the three semicircular canals, which are outgrowths from it or appendages to it. It is called the *utricle* or *auditory pouch.* The smaller sac is called the *saccule* or *auditory sac.* It is situated below and anteriorly, and communicates

with the snail-shaped portion called the *cochlea.* The utricle and saccule communicate with each other.

9. The internal ear is essentially a sac or membranous bag filled with the auditory fluid (endolymph), and having the nerve of hearing distributed over its walls.

10. When the auditory nerve enters the internal auditory opening (meatus auditorius internus), it divides into two nerves, one of which goes to the cochlea (the anterior or cochlear branch), and the other to the vestibule, which is the common name used for utricle and saccule, or all the membranous portion of the labyrinth between the cochlea and the semicircular canals.

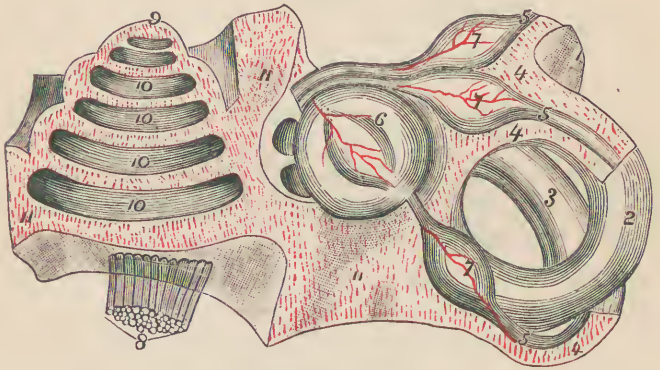
11. The cochlear branch, after breaking up into a number of smaller branches, enters the base of the cochlea, being distributed finally to peculiar structures known as the organ of Corti. This nerve is concerned in determining the quality and pitch of sound.

12. The branch to the vestibule divides into three branches, which are distributed to the utricle, saccule, and semicircular canals. In the walls of the utricle and saccule and the ampullæ of the canals, at the point where the nerves enter, crystals of carbonate of lime, called *otoliths* (ear-stones), are found, producing a white appearance called the *hearing spot* (macula acustica). The function of these has not been definitely determined. That part of this nerve which is distributed to the saccule and utricle, and probably to the semicircular canals, determines the quantity or intensity of sonorous vibrations.

13. The semicircular canals are the organs which assist in maintaining the equilibrium and give the

sense of space. Repeated experiments upon lower animals have demonstrated that these canals can be destroyed without complete loss of hearing, while

Fig. 71.



INTERNAL EAR.

1, 2, 3, semicircular canals; 4, 4, 4, osseous canals; 5, 5, 5, show membranous canals within the osseous, which have been cut at 4, 4, 4; 6, utricle; 7, 7, 7, ampullæ; 8, filaments of the cochlear branch of the auditory nerve; 9, cupola; 10, 10, 10, 10, columnella, or modiolus; 11, 11, 11, bone.

destruction of the cochlea is always followed by complete deafness.

14. When the semicircular canals are destroyed or diseased the equilibrium becomes affected, making it impossible to walk straight, especially if the eyes are closed, and all the movements are uncertain and staggering (Menière's disease).

15. The simplest organ of hearing is a sac filled with fluid containing some otoliths, with the filaments of an auditory nerve distributed over the wall. This is the condition of the auditory organ in most of the invertebrates. The organ is generally confined to the

head, but there are many exceptions to this rule. It is connected with the wing of many insects. Some crustacea have it at the base of the antennæ or feelers, and the clam has its organ of hearing in its foot. Fishes have no external and middle ear; the bones of the head conduct the waves of sound. The amphibians have a middle ear, which first appears in this class, with an ear-drum and Eustachian tube. Birds have an external auditory canal leading to the lateral surface of the head, surrounded by a circle of feathers, but no ear-shell (concha auris). Mammals and pouched animals (marsupialia) have an ear-shell, generally well developed, except in the aquatic members of the mammalian class (some seals, whales, sea-cows, etc.).

16. The centre for the conscious perception of sound is located in the superior convolution of the temporal lobe of the cerebrum. Disease of this convolution may produce deafness or hallucinations of hearing. Cases are authentically reported of persons who are unable to respond to inquiries when spoken, but who grasp the question immediately when written. Disease of the temporal lobe in such has destroyed the memory of sounds, the centres of sight being unaltered. The fourth bulb of the optic thalamus is supposed to be a regulator of all auditory impressions (Luys).

17. The intemperate use of tobacco, especially the practice of smoking cigarettes and blowing the smoke through the nasal passages, may lead to disturbances of hearing by exciting inflammation of the pharynx, which may travel to the middle ear through the Eustachian tube. Alcohol diminishes the acuteness of the auditory sense. The "ringing in the ears" produced

by the use of quinine is familiar to nearly every one. Salicylate of soda produces the same effect. Strychnia stimulates the sense of hearing. Indian hemp (*Cannabis Indica*) perverts the sense of hearing, producing subjective sounds and auditory hallucinations.

QUESTIONS.

SECTION I.

What is the organ of hearing called? Of how many parts is it composed?(1). Describe the external ear(2, 3). Describe the middle ear (4, 5). What changes the tension of the ear-drum?(6). Where is the internal labyrinth?(7). What is the utricle?(8). What fills the internal ear?(9). Where does the auditory nerve enter the ear? How is it distributed? What is the function respectively of the cochlear and vestibular branches?(10, 11, 12). What is the function of the semicircular canals? What is the result of their disease or destruction? (13, 14). Tell what you know of the different forms of ear found in different animals(15). Where is the centre of hearing?(16). What substances diminish the acuteness of the auditory sense?(17).

CHAPTER XIV.

SECRETION AND EXCRETION.

The blood furnishes food for all the tissues of the body, thus enabling them to properly perform their functions. The blood is supplied with material for its development from the alimentary canal and lungs. In order that tissues may work they must not only be supplied with new food-materials, but the products of their activity (ashes of the tissues) must be carried away. The blood also does this, acting as scavenger for the body. Before the food-matters which are taken into the alimentary canal can be absorbed and gain access to the blood-current, they must be changed in their chemical and physical nature. These changes are effected by the action of the so-called digestive fluids (saliva, gastric juice, bile, intestinal juice, pancreatic juice, etc.), which are in turn extracted from the blood-current by the action of certain glandular structures developed in the course of the food-tract. *These fluids are called secretions.* They have a function to perform or important work to do for the body in which they are found. After the constructive matters of the blood have been changed into tissue structures, and as such have performed their work, they are changed into dead and worthless matter, which is taken up by the blood-

current and carried to the different organs of the body whose function is to separate it from the blood and start it on its return to the external world. These substances, so separated from the blood, are called *excretions* (carbonic-acid gas, urea, cholesterine, parts of perspiration, etc.); and the organs which thus purify the blood are called *excretory* organs (lungs in part, liver in part, kidneys, skin, alimentary canal in part). *Excretions have no work to do.* The system has no use for them, and they must be discharged from the body. The milk is generally classified as a secretion. It differs in *direct* function, however, from other determined secretions of the economy. Gastric juice is characterized as a true secretion, because it has an important work to do *for the body which forms it.* Milk also has a function to perform in furnishing food for the offspring of the mother, *but not for the body which forms it.* The mammary glands bear the relation of excretory organs to bodies in which they are found, as during their activity they separate certain substances from the blood used in making the milk, which seems to be a necessary condition for the health of the animal during the early days of lactation.

The constituents of milk do not exist pre-formed in the blood, but are manufactured in the mammary gland. There are certain glands in the body not supplied with an excretory duct, and whose functions are unknown, or known only in part. These are called "*ductless* glands," examples of which are the spleen, suprarenal capsules, thymus, and thyroid glands.

In passing through the lungs the blood is said to be rendered pure and made fit for nutrition. This is true

with reference to the respiratory gases. Carbon dioxide as an effete matter is largely separated, and oxygen as a nutritive matter gains access to the blood-current as it passes through the pulmonary capillaries. The venous blood in the right ventricle contains effete matters from all parts of the system, in addition to nutritive matters furnished by the thoracic duct and liver and that not consumed in its passage through the systemic capillaries.

When the venous blood is thrown through the lungs, it parts with much carbonic-acid gas (losing but a small quantity of other effete matter), and gains oxygen. As it enters the left side of the heart, it contains the same impurities minus the CO_2 lost, and as it gains no new constructive matter except oxygen, the nutritive power of arterial blood (excepting oxygen) is no greater than that in the right ventricle. If the interchange of gases in the lungs be arrested, the venous blood with its constructive and effete matters passes over into the arterial system, blanketed with carbonic-acid gas. It now visits the tissues, and these refuse to extract food-materials in the presence of CO_2. If the interchange of gases in the lungs be resumed, the same kind of blood loses CO_2 and gains oxygen. It visits the tissues with the same constructive matters, which, now being presented in the presence of oxygen, are used for tissue work and growth. As the arterial blood laden with effete material passes through the various emunctories of the body (skin, glands, kidneys, liver) it is changed in part, and passes into the venous radicles much purified, gaining but a small relative amount of impurities in these organs as compared with the quantity lost.

SECTION I.

THE KIDNEYS.

1. The **kidneys** are typical excretory organs. They aid in purifying the blood by separating from it an excretion (urine) which has no function to perform, and which must be thrown from the body.

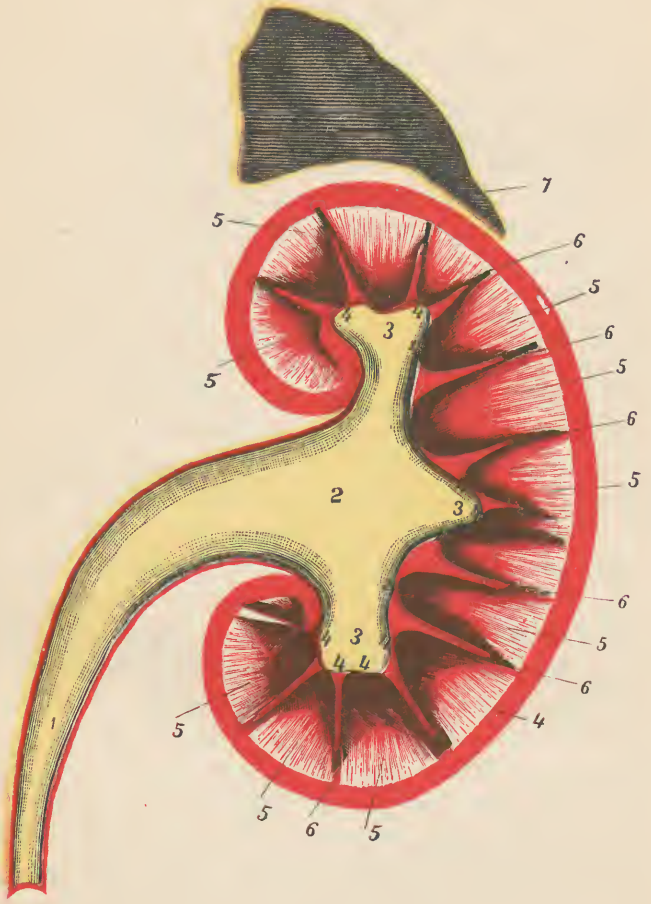
2. They are two in number (cases have been encountered where but one kidney existed), situated in the abdominal cavity in the region of the loins, one on each side of the vertebral column, behind the peritoneum. They are imbedded in a mass of adipose tissue, and communicate with the bladder by a tube from sixteen to eighteen inches long, called the *ureter*.

3. Each kidney weighs from four to six ounces in the male, and from one-half to one ounce less in the female. The right kidney is generally a little lighter than the left. They are each about four inches long by two to two and a half inches wide, and from one to one and a half inches thick, and extend from the twelfth dorsal to the third lumbar vertebra, the right kidney being situated lower than the left on account of the presence of the liver on the right side.

4. The kidney has been compared in shape to a bean, being a little larger above than below. The constriction in its circumference is called the notch or hilum; it looks inward, and from this point the ureter comes off, becoming narrower as it leaves the gland. The enlarged beginning of the ureter, which shows in vertical section of the organ, is called the *pelvis*.

5. The investing **tunics** of the kidney are two in number—the *external*, containing fatty matter, and the

Fig. 72.



KIDNEY.

1, ureter; 2, pelvis of the kidney; 3, 3, 3, infundibula; 4, 4, 4, 4, 4, 4, calices; 5, 5, 5, 5, 5, pyramids of Malpighi; 6, 6, 6, 6, 6, columns of Bertin; 7, suprarenal capsule.

internal or proper capsule, composed of fibrous connective tissue. This latter coat is continued inward at the hilum to line the pelvis and to form the calices, which receive the opening of the tubes in the pyramidal portion of the gland. This capsule is smooth, and can easily be stripped from the surface of the organ.

6. In vertical section the kidney exhibits two distinct structures—an external, thin, granular part, called the *cortex*, or cortical layer, which is about one-sixth of an inch thick, reddish in color, and dips down at intervals into the deeper portion; and the deeper part, called the pyramidal portion. It is darker than the cortex, and composed mostly of tubes and blood-vessels.

7. The **tubes** of the deeper part are arranged in the form of pyramids, with their apices toward the pelvis and their bases toward the cortex. These pyramids number from eight to eighteen, and are called the *pyramids of Malpighi.* The Malpighian pyramids are made of smaller pyramids, the so-called *pyramids of Ferrein.* These last are made, each, of about one hundred straight tubes of Bellini, which radiate from the apices of the Malpighian pyramids to their bases, and then pass into the cortical layer to become continuous with the tubes in this part.

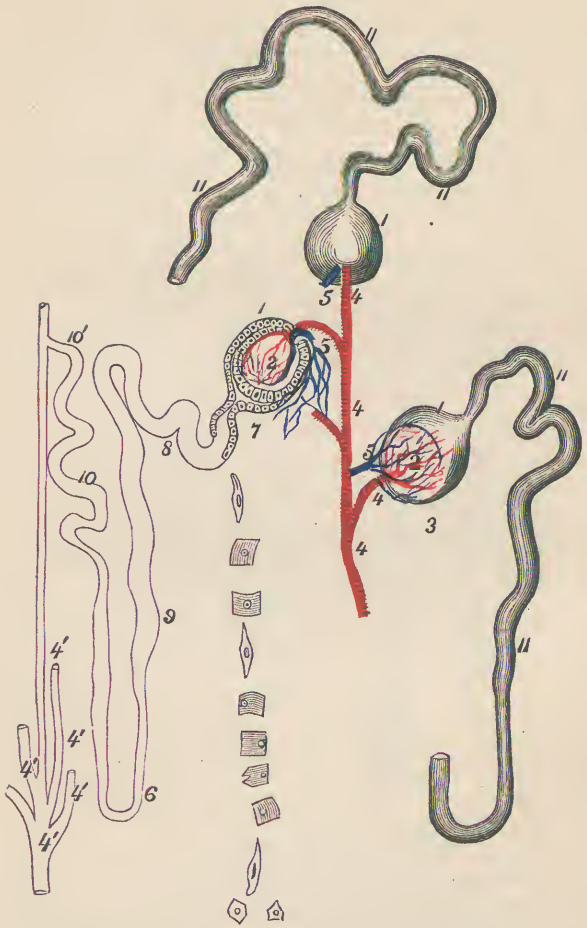
8. The cortical portion is generally considered the active part of the kidney. Here the water and poisonous principles found in urine are separated from the blood. Occurring throughout the cortical portion are numbers of little round bodies called Malpighian bodies, measuring $\frac{1}{250}$ to $\frac{1}{120}$ of an inch in diameter. They are simply the dilated extremities of the convoluted tubes.

They are surrounded by a delicate membrane called the *capsule of Bowman* or of *Müller*, which is continuous with the membrane of the tubuli uriniferi, and contain a tuft of blood-vessels which are surrounded by a layer of epithelial cells, in addition to a layer which lines the capsule. This tuft of vessels is called the *glomerulus*, and here is where the water and some of the inorganic matters of the urine are separated from the blood.

9. Leaving the Malpighian body, the tube immediately becomes constricted into the neck; beyond this the tube is much convoluted, and has a diameter of nearly $\frac{1}{500}$ of an inch. It is lined by delicate epithelium, which has a peculiar appearance and has the power to separate the solid parts of the urine from the blood—a function which is probably shared by the large parts of the tubes of Henle.

10. The convoluted tubes of the cortex just described, after a slight change in shape dip down into the pyramids and return again to the cortex, where they pursue a tortuous course, and open finally in the branches of the tubes of Bellini, which, arranged as the pyramids of Ferrein, constitute the pyramids of Malpighi, or the medullary portion of the kidney. Thus the Malpighian bodies communicate with the tubes of the pyramids, which open in clusters of from one to twenty-five in the calices. These run together to form the infundibula, three of which form the pelvis of the kidney, this being the beginning of the ureter, which carries the urine separated from the blood in the Malpighian bodies and tubes to the bladder. That part of the cortex which dips down between the pyramids is called the *columns of Bertin.*

Fig. 73.

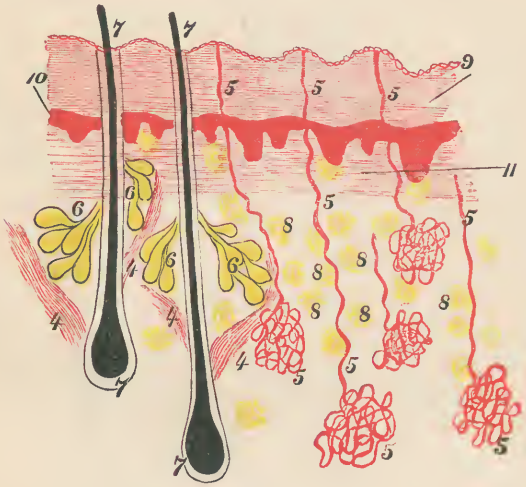


1, 1, 1, Malpighian bodies; 2, 2, Malpighian tuft or glomerulus; 3, capsule of Bowman or the Malpighian capsule; 4, 4, 4, artery; 5, 5, 5, vein; 4′, 4′, 4′, 4′, straight tubes of Bellini; 7, neck; 8, convoluted tube, Schachowa's tube; 6, Henle's loop, convoluted and irregular distal tube; 10′, curved collecting or communicating tube; 11, 11, 11, tubuli uriniferi.

11. The **liver** is the largest gland in the body. It weighs from fifty to sixty ounces, is situated in the abdominal cavity below the diaphragm, mostly on the right side of the median line, and has five lobes and five fissures.

12. It is supplied with blood by the portal vein and hepatic artery, and is an organ of complex function.

Fig. 74.



SECTION OF HEALTHY SKIN.

4, 4, 4, 4, arrector pili muscles; 5, 5, 5, 5, sudoriparous or sweat glands and their excretory ducts or sweat-canals; 6, 6, 6, 6, sebaceous glands; 7, 7, 7, 7, hair and hair-follicles; 8, 8, 8, adipose or fatty tissue; 9, epidermis, horny layer; 10, Malpighian layer or rete mucosum, corium, or cutis vera.

13. The active parts of the liver are the liver-cells, which are but $\frac{1}{1000}$ to $\frac{1}{1200}$ of an inch in diameter.

They have the power to separate the secretions and excretions found in the bile from the blood, as well as to manufacture glycogen, a sugar-like substance formed by the liver from before birth until death.

The liver is an excretory as well as a secretory and manufacturing organ.

14. The **skin** is one of the most important structures of the body. It surrounds the body as a blanket and protects it from injury. It contains important nerve-terminations, concerned with general sensibility and tactile sensation, as well as numerous sweat and sebaceous glands and modified epidermal appendages (hair and nails).

15. The entire length of the sudoriparous or sweat-tubes in the human body has been computed to be about two and a third miles. The skin performs from one-fortieth to one-fiftieth of the respiratory function. The quantity of perspiration given off in twenty-four hours is said to average about two pounds. The quantity varies, however, with exercise, the kind and quantity of food taken, the activity of the kidneys, alimentary canal, and lungs, and the condition of the surrounding atmosphere.

QUESTIONS.

SECTION I.

What are the kidneys? What do they do?(1). Give the number and location of the kidneys. How do they communicate with the bladder?(2). Give the weight and dimensions of the kidney(3). What is the shape of the kidney? Where is the hilum?(4). How many tunics has the kidney? Name them(5). How many structures are seen on vertical section of the kidney? Where is the cortex? How

thick is it? What is its color?(6). Describe the formation of a pyramid of Malpighi. What are the pyramids of Ferrein? Of what are they composed?(7). What structures are found in the cortex? What is the active part of the kidney? Describe a Malpighian body(8). What is the functional importance of the convoluted tube?(9). Begin at a Malpighian body and name the parts over which the urine goes on its way to the bladder(10). What is the weight of the liver? How many lobes has it? How many fissures has it?(11). What vessels supply it with blood?(12). What is a liver-cell? What is its size? Name some of its powers(13). Tell what you know of the skin(14, 15).

CHAPTER XV.

ON THE INTEMPERATE USE OF ALCOHOL.

Man is a being of a complex nature composed of matter and mind. These are interdependent: what affects one affects the other in some measure. There is a theory which denies this complex character: it is called materialism. It advocates the theory that soul or mind in its various manifestations is the result of the organization of particles of matter. Man is, according to this view, organized matter. Language, however, is constructed upon a theory the very opposite of this. Matter and mind in our lexicons and in the general use of terms applicable to them are regarded as entirely distinct. Neither of these views, however, conflicts in regard to their *reciprocal action.* The moral nature of man is that of which we predicate affection, motive, conduct, behavior, duty, will, and desire, and these are so blended with the strictly intellectual processes as to indicate an interdependence of the mental states and functions more immediate than that of the body and the intellect. The whole human fabric is so constructed that each portion of it is in sympathy with the remainder.

A grave question comes up when it is asked, What effect has the use of narcotics and stimulants, such as are regarded as non-nutrients, on man's moral being? This question must be dissociated from that which pertains to the medical use of these agents. There are

strong reasons to believe that the habitual and excessive use of these preparations are of serious and incalculable injury to man regarded as a moral being.

It is conceded that the drugs alluded to appeal to the nervous system, and in this way affect the mental functions most directly. The most common narcotic in use is probably tobacco, but cases which demonstrate its injury to the morals are so few that no dogmatic opinion can be given, except that its excessive use in the cigarette form, as also in the ordinary ways of chewing, smoking, and snuffing, has a tendency to foster in the young inclinations destructive of a high moral tone. Hasheesh, opium, chloral, when used habitually and excessively, have been known so to injure the health and disarrange the mental action that the moral sense protests against their use. Under the prescription of a physician they may be used to allay pain or produce sleep in restless invalids, but the unprofessional use of them is extremely fatal to mind and morals, dulling and stupefying one and producing erratic action in the other. The excessive habitual use of these artificial stimulants creates a morbid moral state unfavorable to the promptings of duty, and promoting a condition unsuited to meditation on moral subjects, especially where the victim is deprived temporarily of the stimulus. The longing, the irrepressible sense of uneasiness, the restlessness, which the sufferer, deprived of his habitual ration, endures, indicates a moral as well as a mental state unhealthy and perverted.

The habitual and excessive use of alcoholic beverages is harmful in the extreme to the moral nature. Startling facts corroborate this opinion. They are his-

toric. Scarcely a community is exempt from the evils of intemperance. One result most common is the loss of self-respect. Men addicted to this vice descend to the grossest immoralities. Before the taste and burning desire for liquor was acquired they were decorous and dignified; but, degraded by the demoralizing appetite, they present the most pitiable spectacle of self-humiliation, all moral excellence disowned or lost. Nor is this result common to men of moderate talents or low extraction. Some of the brightest geniuses have exiled themselves from the social circle of which they were ornaments, or have been banished therefrom, because of their violation of the courtesies and conventionalities of polite life. They have deliberately forfeited that conservative element in human nature on which are based true dignity and manliness.

This baneful habit makes fearful inroads on the social affections. Friendships of long standing have been broken up because of the unreasonable exactions on patience and sympathy demanded by the inebriate. Drunken husbands have exercised a tyranny over refined, cultured, and amiable wives till, after long years of endurance, the sufferer has gone down broken-hearted to the grave. These are not cases confined to a few families: they are numbered by the thousand. The paternal relation has been made the occasion of untold pain to children who have become, under the rule of an intemperate father, the heirs of privation, cruelty, and neglect. The paternal feeling has gradually been crushed out. There are records of feminine frailty of like character where the mother-instincts have been so far obliterated that one shudders to think of a

degradation so abject being possible to the womanly nature.

Loss of manly ambition is one of the sad results of this habit. The foe has invaded the precincts of the bar, the senate-chamber, the sacred desk, and hurled down to the dust brilliant men, who sacrificed honor, purity, holiness, popular affection, and flattering possibilities of wealth and fame at the shrine of this evil. This is a melancholy page in the history of many great names.

The great moral monitor, *the conscience*, often is made to hush its admonitions and become silent or dead. Acts the most abhorrent to men sober, by men drunk are committed without shame. Inflamed by a species of madness produced by drink, men perpetrate the darkest deeds. In fact, criminals have fortified their failing courage by repeated draughts of liquor to nerve them to the commission of some premeditated crime. Our civil tribunals are tortured with cases which would never be brought into court but for crime committed by men in a state of intoxication. So enormous, so brutal, have been some offences against the rights of society, and of individuals as well, that serious doubts arise whether the criminal has a conscientious scruple. The wreck of this high moral authority and guide is a sad monument of depravity.

There is another great moral force which is not exempt from the ravages of intemperance—*the will.* This power is the crowning glory of human nature. It is a gift of imperial authority with which man is dowered. When that is enfeebled or destroyed, the creature is unmanned, the sceptre falls from his hands. This regal quality may be enslaved by the vice of

intemperance, and then the fate of the unfortunate victim is sealed. There is then no prospect, no promise, of reformation. The farther the victim goes, the greater the momentum toward the inevitable doom. The facility of wrong-doing and the tendency grow in a fearful ratio, until he that was a strong man in will-power is enslaved, and is impelled along on the down grade to the last asylum, the grave.

Thus we trace the effects of a habit that has been a problem to physician, philosopher, jurist, and minister. It is a question interesting to all students of human nature. The humanitarian is startled at the ruin the evil entails on the moral nature. The philanthropist cannot contemplate unmoved the arena of disaster on which scenes so terrible transpire. The ravages of the monster are universal in their extent and complete in their character. The keenest moral sense is deadened, ennobling aspirations are extinguished, moral beauty is eclipsed. Chastity is ridiculed, virtue defamed, honesty despised, honor debased. Passions reign, selfishness is supreme. All excellence loses its lustre. These and many others are the bitter fruits of this appalling evil.

Young and brilliant minds, noble and generous natures, yield most easily to the pressure of high artificial stimulation. At the beginning of the formation of the habit the effect on body and mind is invigorating and inspiring for a season. Life becomes during the delusive inflation a delirium of delight. The victim feels richer, more generous, more genial. The present is radiant and rosy, the future aflame with an aureole of glory. To these ignitable souls drink seems the elixir of life, the fabled nectar of the gods. But at the

last, when the chains of habit are riveted, the victim, no longer free, but a slave, experiences all the horrors of remorse and self-condemnation. But his will is too enfeebled to break the shackles or resist the wand of the enchantress. He is numbered with that vast army, nearly one hundred thousand strong, who annually hasten to that dreary domain where the drunkard's journey ends.

These unfortunates often leave behind to their offspring a legacy of mental and moral derangement. In a work entitled *A Physician's Problems* the history of four generations of a family is given to illustrate this theory of heredity. The facts are related as corroborative of the opinion that mental and moral tendencies and characteristics of the offspring are in a large measure affected by the vicious habits of intemperate parents. Homicidal and suicidal inclinations, melancholy, disordered affections, gross impulses, were tracked along down to the fourth generation, when, fortunately, the race terminated. The student is referred to the collection of facts in the book named as of great scientific import on this subject.

There are those who have never experienced in themselves the dreadful effects of intemperance, having never used intoxicating liquors. The abstinence in these persons—and they are numerous—appears to favor the impression that except in disease no other stimulus is needed for a full mental, moral, and physical manhood than that which food, rest, occupation, and pure air supply. The moral well-being of the human race would no doubt be best subserved by plain diet, pure emotion, and high thought.

APPENDIX.

EMERGENCIES, AND HOW TO MEET THEM.

When possible all accidents of any gravity should be treated by a practising physician or surgeon. Unfortunately, however, such skilful service is not always immediately available, and it then becomes the duty of the bystanders and friends to render what aid they can until the arrival of a more competent person. When such service has been properly directed, it frequently happens that the patient has passed beyond the line of danger before the medical man arrives: many lives are thus saved by the prompt action of the unprofessional.

Hemorrhage.—The loss of blood is probably the most alarming condition resulting from injury. It can be temporarily controlled by any calm and determined person. The bleeding part should always be elevated. When the wound is small and incised (clean cut), and the blood is not thrown out in jets, simply pressing the edges of the wound together will suffice to arrest the hemorrhage. To this may be added cold or moderately hot water and pressure by a bandage. The wound should be cleansed of foreign bodies, and the bandage *not too tightly* applied. It is unnecessary to irrigate small wounds with water, as frequently the water carries into the wound foreign matter which gives rise to inflammation and suppuration. Put-

ting the divided tissues in proper position and dressing the wound in its own blood is considered good treatment.

Bleeding from arteries can be controlled by pressing on the vessel above or to the heart-side of the wound. When arterial hemorrhage is severe, it may be controlled by an improvised tourniquet, as described on page 125. Bleeding from an artery is not continuous, as in the case of a wounded vein, the blood being thrown out with each contraction of the heart, and is of a bright-red color.

Epistaxis (*nose-bleed*).—Hemorrhage from the nose is sometimes so severe as to endanger life. It may be arrested by sitting with the head upright, making deep inspiratory efforts, removing the collar and all constrictions from the neck. Inspire through the nose, expire through the mouth; raise the arm on the bleeding side vertically above the head, and press the bleeding side with the fingers of the opposite hand. Apply cold to the nose and nape of the neck, testicles, or mammæ. If these measures fail, as a final resource the anterior and posterior openings of the nose should be plugged or an ice-water and salt solution (two tablespoonsful of salt to one tumbler of water), or a solution of some of the salts of iron, persulphate or pernitrate, should be injected.

Bleeding from the mouth, resulting from wounds and ulcers, can often be controlled by rinsing the mouth with a solution of either oak-bark, alum, tannic acid, or vinegar, or by holding pieces of ice in contact with the bleeding surface.

Bleeding following the extraction of teeth may be arrested by filling the cavity with either wax (beeswax will answer the purpose), plaster of Paris, a cobweb, a hot needle, or decoctions of cranesbill (*Geranium maculatum*),

which grows abundantly in nearly all North American woods.

Vomiting of blood (*hæmatemesis*) is due to some injury of great gravity or to disease of the stomach, gastric ulcer and cancer, or alcoholic diseases of the liver. Blood from the stomach is dark in color, mixed with the contents of the stomach, and is acid in reaction. Blood from the lungs (*hæmoptysis*) is bright-red in color and frothy.

Absolute quiet in the recumbent posture must be enjoined, and all sources of excitement removed. Apply ice-bags to the abdomen or thorax. Small pieces of ice also may be swallowed continuously; tannic acid, salt, alum, and vinegar may be taken in proper quantities at intervals. Ether, applied to the abdomen, is also a favorite treatment.

Hemorrhage from the bowels, due to hemorrhoids, ulcers, etc., may be controlled by the injection of cold water, starch, and laudanum, and the maintenance of perfect quiet in the recumbent posture.

Gunshot wounds always require careful treatment. The patient may be aroused from shock or collapse by the application of heat to the extremities and epigastrium (over the stomach), with the administration of stimulants —whiskey and hot water, or ammonia. The proper cleansing of the wound and extraction of foreign bodies had better be entrusted to the skill of the physician.

Rabid Dog-bites.—Wash the wound well, and suck it as long as the blood will flow. When bitten on a part covered by clothing, the teeth will be cleaned before reaching the skin, and no saliva may reach the wound. When bitten on an uncovered part, it is best to cut (excise) the part out and apply a red-hot iron (*actual cautery*). When the wound occurs on the toes or fingers the application of a

ligature above the bite may prevent the poison from entering the general circulation. This treatment, however, is of doubtful efficacy.

Snake-bite.—A venomous snake, as a rule, has a triangular head, bearing small scales, short tail, a limited number of teeth, two large fangs, vertical pupil, and a marked constriction behind the head at the neck. The tobacco-pipe snake, whip-cord snake, rattlesnake, adder, viper, and cobra de capello are among the most venomous reptiles. The bite of the viper and adder are rarely fatal to adults. The bite of the tobacco-pipe snake will kill a full-grown man in fifteen minutes. That of the rattlesnake and cobra is fatal to small animals in a few seconds. The fangs of venomous snakes are hollow, and communicate with the poison-sac by a duct, and a snake-bite is as dangerous when effected through clothing as when the parts are unprotected.

The wound should be cleansed and sucked or cupped, or a piece cut out to facilitate bleeding. A ligature should be tightly applied around the limb above the wound. The red-hot iron is a favorite method of treating the wound by many. The usual treatment in India, among hunters, is to excise the bitten part, and, after mixing powder with the blood on the surface of the wound, ignite it; which proves an effective cautery. Virginia snakeroot, arsenic (contained in the "Tanjore pill," which is a favorite Indian remedy), bichloride of mercury, and iodide of potassium are also favorite remedies, but must be administered by a physician. Forced exercise and large doses of whiskey and ammonia are active agencies in overcoming the depressing effects of the poison, and must be resorted to until the venom wears off. If exercise be prolonged and sufficiently violent, the skin may eliminate some of the poison.

Stings and bites of insects may be treated with cold applications to the part, touching it with ammonia, liquor potassæ, and rubbing with vaseline or olive oil.

Frost-bite.—Keep the patient away from the fire and in a cold room; rub the frozen parts with snow or mashed ice, then ice-water, and *gradually* restore the temperature, finally wrapping the parts in flannels, at the same time administering small quantities of whiskey and hot water. *Chilblain* requires good hygienic surroundings, exercise, good food, and warm clothing. Belladonna and soap liniment or tincture of iodine may be applied locally.

Burns vary in degree, and the danger is in proportion to the degree and extent of the burn. Generally, when more than one-third of the surface of the body has been burned, surgeons regard recovery as doubtful. The charred bands of clothing should be cut off, and the burnt surface covered with soft cloths or cotton saturated with vaseline, olive oil, and carbolic acid, or vaseline and bismuth, to thoroughly protect the injured surface from the air. A favorite application in iron-works and other places where burns are frequent is a mixture of equal parts of lime-water and linseed oil (*Carron oil*). Where the area burned is small, the application of cold, flour paste, or simple vaseline will prove an efficient remedy. The epidermis or blister should not be removed.

Foreign Bodies in the Air-passages.—Pieces of coin, pins, particles of food, etc. occasionally find their way into the air-passages and produce marked symptoms of suffocation.

A forcible blow on the back may dislodge the body immediately after its introduction. Hold the patient by the ankles, head down; shake the body from side to side, at the same time striking forcible blows between the

shoulders. If this fails, hastily summon a physician. Forced vomiting in such cases is of no promising benefit.

Foreign Bodies in the Nose.—Early in life children frequently introduce small marbles, beans, peas, pebbles, and other articles into the nasal cavities. Some of these absorb moisture, and so increase in size that much care and skill is necessary to their extraction. A stream of water may be run through the nasal cavity to wash it out, or it may be dislodged by a forcible act of sneezing induced by the inhalation of some sternutatory, as snuff, fine tobacco, or pepper. When these efforts fail a physician must be summoned.

Foreign Bodies in the Ear.—Insects of various kinds sometimes find access to the external ear-canal and produce much annoyance and pain by their presence. Fill the ear with warm water or salt and vinegar or olive oil. This will generally float the insect out. Saturate a piece of cotton or wool with ether or chloroform and plug the ear. This will arrest the movements of the insect, and it may then be washed out by a stream of water or by filling the ear with oil. Impacted wax and other hard foreign bodies are better entrusted to the physician's treatment.

Foreign Bodies in the Eye, as loose hair, grains of sand, etc., can be extracted by pulling the upper eyelid down and out over the edge of the lower one as far as possible, and allow it slowly to return in such a manner that the lashes of the lower lid sweep over the inner surface of the upper. Several repetitions of this may prove successful, or the lids may be alternately everted. A stream of clean water, or water and white of egg mixed, or a flaxseed introduced into the eye, will often bring away the offending body.

Drowning.—The length of time a body can remain completely under water and be restored is thought not to exceed five minutes. Still, cases of seeming authority are recorded where life was restored after fifteen minutes of complete immersion. The condition of syncope probably deferred the demand for oxygen in cases of this kind. The mouth and air-passages, as far as possible, should be cleaned of mucus and foreign matter; friction should be applied to the extremities with flannels, ammonia, and whiskey. The vapor of ammonia should be applied to the nostrils. Wrap the body in blankets and apply heat—bottles of hot water, hot irons, etc. Draw the tongue well out of the mouth, and hold it with a pair of forceps or a handkerchief. Lay the patient on his back and alternately compress and relax with some force the thorax and upper part of the abdomen. By firm pressure the air is expelled from the lungs, and by relaxing the cavity of the thorax it returns to its normal size and draws fresh air into the lungs. Continue this for a long time, and as consciousness returns gradually administer stimulants.

In the method of Sylvester the patient is laid on the back with head and shoulders slightly elevated. The resuscitator stands at the head of the patient, and, grasping the arms between the elbows and wrists, makes them meet vertically above the head. He holds them there for a few moments, then returns them to the sides, and compresses the sides of the thoracic cavity. These movements are continued so long as there may be hopes for a restoration.

The method of Marshall Hall consists in laying the patient on the side, with the corresponding arm to the back. The body is then slowly rolled over on the face and pressure brought to bear on the back and sides of the thoracic cavity. This forces impure air out of the lungs, and, as the patient is rolled back to the recumbent posture,

the pressure on the thorax is removed and the air rushes into the lungs. If none of these movements succeed, the trachea may be opened and a small bellows used to introduce air.

Poisoning.—A physician should always be called in in cases of poisoning. It is always safe to encourage vomiting and clean out the stomach. When acids have been swallowed, empty the stomach. Administer any alkali—soapsuds, lime-water, baking soda, chalk, or whitewash from the walls. When alkalies have been taken, encourage vomiting by warm water and salt or mustard; administer raw eggs, vinegar, butter, and milk.

Sun Fever or **Sunstroke** attacks by preference persons of intemperate habits. Place the patient in the shade in a recumbent posture; remove all the clothing, and pour cold water from a vessel, held several feet above the ground, first on the head, then on the thorax and abdomen, and last on the extremities. Bromide of potassium, administered internally by mouth or rectum, is of great benefit when the pulse becomes weak and exhaustion threatens, and the skin is cold. Cold water will then do no good, as stimulants are indicated. Brandy or whiskey and milk and ammonia will now be of service. Mustard plasters over the abdomen and at the back of the neck should be applied after the more active treatment has been rendered.

TABLE

GIVING NAME, NERVOUS SUPPLY, ORIGIN, INSERTION, AND FUNCTION OF THE MUSCLES OF THE HUMAN BODY.

B. P. = Brachial Plexus; L. P. = Lumbar Plexus; S. P. = Sacral Plexus; C = Cervical; S = Sacral; D = Dorsal; L = Lumbar.

Muscles acting on the Upper Extremity.

Name.	Nervous Supply.
1. Deltoid,	Circumflex, B. P.
2. Supraspinatus,	Suprascapular, B. P.
3. Pectoralis major,	Ant. thoracic, B. P.
4. Teres major,	Lower subscapular, B. P.
5. Latissimus dorsi,	Subscapular, B. P.
6. Coraco-brachialis,	Musculo-cutaneous, B. P.
7. Infraspinatus,	Suprascapular, B. P.
8. Teres minor,	Circumflex, B. P.
9. Subscapularis,	Subscapular, *B. P.*
10. Biceps,	Ext. cutaneous, B. P.
11. Brachialis anticus,	Ext. cutan. and mus.-spiral, B. P.
12. Triceps,	Musculo-spiral, B. P.
13. Anconeus,	" B. P.
14. Supinator longus,	" B. P.
15. " brevis,	Post. interos. br. mus.-spiral, B. P.
16. Pronator radii teres,	Median, B. P.
17. " quadratus,	Ant. interos. branch of median, *B. P.*
18. Flexor carpi radialis,	Median.
19. " ulnaris,	Ulnar.
20. Palmaris longus,	Median.
21. Extensor carpi radialis longior,	Musculo-spiral, B. P.
22. " " " brevior,	Post. interos. branch of mus.-spiral.
23. Extensor carpi ulnaris,	*Post. interosseous.*
24. Flexor sublimis digitorum,	Median.

Name.	Nervous Supply.
25. Flexor profundus digitorum,	Median and ulnar.
26. Lumbricales (4 in number),	" "
27. Flexor brevis minimi digiti,	Ulnar.
28. Extensor communis digitorum,	Posterior interosseous.
29. " minimi digiti,	" "
30. " indicis,	" "
31. Palmar interosseous (3 in number),	Ulnar.
32. Dorsal interosseous (4 in number),	*Ulnar.*
33. Flexor longus pollicis,	Ant. interosseous.
34. " brevis pollicis,	Median and ulnar.
35. Opponens pollicis,	Median.
36. Extensor ossis metacarpi pollicis,	Posterior interosseous.
37. " primi internodii pollicis,	" "
38. " secundi internodii pollicis,	" "
39. Adductor pollicis,	Ulnar.
40. Abductor pollicis,	*Median.*
41. Abductor minimi digiti,	Ulnar, B. P.
42. Opponens minimi digiti,	*Ulnar, B. P.*
43. Palmaris brevis,	Median.
44. Subanconeus,	*Musculo-spiral.*

Muscles acting on the Lower Extremity.

1. Psoas magnus,	Ant. branches of L. P.
2. Iliacus,	Ant. crural, L. P.
3. Pectineus,	Ant. crural, access., obturator, obturator, L. P.
4. Tensor vaginæ femoris,	Superior glutcal, S. P.
5. Gluteus maximus,	Inferior gluteal.
6. " medius,	Superior gluteal, S. P.
7. " minimus,	" " S. P.
8. Adductor longus,	Obturator, L. P.
9. " magnus,	" L. P., and great sciatic.
10. " brevis,	" L. P.
11. Gracilis,	" L. P.
12. Pyriformis,	Sacral plexus.
13. Obturator internus,	" "
14. " externus,	Obturator, L. P.
15. Gemellus superior,	Sacral plexus.
16. " inferior,	" "
17. Quadratus femoris,	*Sacral plexus.*
18. Biceps (outer ham-string),	Great sciatic, S. P.

Name.	Nervous Supply.
19. Semimembranosus (inner hamstring),	Great sciatic, S. P.
20. Semitendinosus (inner hamstring),	" " S. P.
21. Popliteus,	Internal popliteal.
22. Rectus femoris,	Anterior crural, L. P.
23. Vastus externus,	" " L. P.
24. " internus,	" " L. P.
25. Crureus,	" " L. P.
26. Sartorius,	*Anterior crural, L. P.*
27. Tibialis anticus,	Anterior tibial.
28. Peroneus tertius,	" "
29. Gastrocnemius,	Internal popliteal.
30. Soleus,	" "
31. Plantaris (has longest tendon in the body),	" "
32. Tibialis posticus,	Musculo-cutaneous.
33. Peroneus longus,	"
34. " brevis,	*Musculo-cutaneous.*
35. Flexor longus digitorum,	Posterior tibial.
36. " brevis digitorum,	Internal plantar.
37. " accessorius,	External "
38. Lumbricales (4 in number),	Internal and external plantar.
39. Flexor brevis minimi digiti,	External plantar.
40. Extensor longus digitorum,	Anterior tibial.
41. " brevis digitorum,	" "
42. Plantar interossei (3 in number),	External plantar.
43. Dorsal interossei (4 in number),	*External plantar.*
44. Extensor proprius pollicis,	Anterior tibial.
45. Flexor longus pollicis,	Posterior "
46. " brevis pollicis,	Internal plantar.
47. Adductor pollicis,	External "
48. Transversus pedis,	" "
49. Abductor pollicis,	*Internal plantar.*
50. " *minimi digiti,*	*External* "
51. Suberureus,	Ant. crural.
52. Psoas parvus,	*Lumbar.*

MUSCLES ACTING ON THE SPINE, HEAD, NECK, AND SCAPULA.

1. Supraspinales (6, all C.),	Internal post., branches C.
2. Interspinales (6 C., 3 D., 4 L.),	" " branches C.
3. Spinalis dorsi (4 to 8 in number),	External post., branches L. and D.

Name.	Nervous Supply.
4. Spinalis colli (2 to 4 in number),	External post., branches C.
5. Rectus capitis posticus major,	Sub- and great occipital.
6. " " " minor,	" " "
7. Semispinalis dorsi,	Internal post., branches D.
8. " colli,	" " branches C.
9. Multifidus spinal,	" " branches D., L., S.
10. Rotatores spinal (11 pair, all D.),	" " branches D.
11. Obliquus inferior,	Sub- and great occipital.
12. Intertransversales (7 C., 12 D., 4 L.),	Int. post., branches C., D., L.
13. Complexus,	Internal posterior, C.
14. Biventer cervicis,	Sub- and great occipital.
15. Obliquus capitis superior,	*Sub- and great occipital.*
16. Rectus abdominis,	Lower intercostal, ilio-hypogastric, and ilio-inguinal.
17. Obliquus internus,	
18. " externus,	
19. Intercostales interni (11 pair),	Intercostal.
20. " externi (11 pair),	"
21. Longus colli (3 portions),	Lower C.
22. Scalenus anticus,	Deep branches, C. P.
23. Erector spinæ,	Ext. post. branches, L. and D.
24. Sacro lumbalis,	" " " L. and D.
25. Musculus accessorius,	" " " L. and D.
26. Cervicalis ascendens,	Ext. post. branches, C.
27. Longissimus dorsi,	" " " L. and D.
28. Transversalis colli,	" " " C.
29. Trachelo-mastoid,	" " " C.
30. Latissimus dorsi,	Long subscapular.
31. Quadratus lumborum,	*Anterior branches, L.*
32. Rectus capitis anticus major,	Suboccipital and deep C.
33. " " " minor,	" " C.
34. Trapezius,	Spinal accessory and C. P. (3 branches).
35. Splenius capitis,	External posterior, C.
36. " colli,	" " C.
37. Scalenus medius,	Deep branches, C. P.
38. " posticus,	" " C. P.
39. Levator anguli scapulæ,	" " C. P.
40. Sterno-cleido-mastoid,	" " C. P. and sp. access.
41. Rectus lateralis,	*Suboccipital and deep brs.* C. P.
42. Pectoralis minor,	Anterior thoracic, B. P.
43. Serratus magnus,	Posterior " B. P.

Name.	Nervous Supply.
44. Rhomboideus major,	Fifth C.
45. " minor,	" C.
46. Subclavius,	*Subclavian (br. fifth and sixth C.).*
47. Pyramidalis,	Ilio-inguinal.
48. Transversalis,	*Lower intercostal, ilio-hypogastric, and ilio-inguinal.*

MUSCLES ACTING ON THE EXTERNAL EAR, TYMPANUM, AND SOFT PALATE; ALSO, MUSCLES OF EXPRESSION, PHONATION, AND DEGLUTITION.

1. Platysma myoides,	Seventh pair and C. P.
2. Corrugator supercilii,	Supraorbital and seventh pair.
3. Pyramidalis nasi,	Seventh pair.
4. Levator labii superioris alæque nasi,	" "
5. Dilator naris posterior,	" "
6. " " anterior,	" "
7. Compressor nasi,	" "
8. " narium minor,	" "
9. Depressor alæ nasi,	" "
10. Levator labii superioris,	" "
11. " anguli oris,	" "
12. Zygomaticus major,	" "
13. " minor,	" "
14. Levator labii inferioris,	" "
15. Depressor labii inferioris,	" "
16. " anguli oris,	" "
17. Buccinator,	Fifth and seventh pair.
18. Risorius,	Seventh pair.
19. Orbicularis oris,	" "
20. Occipito-frontalis,	*Oc. p. seventh pair; fr. p. fifth and seventh pair.*
21. Crico-thyroid,	Superior laryngeal.
22. Crico-arytenoideus posticus,	Inferior "
23. " lateralis,	" "
24. Thyro-arytenoid,	" "
25. Arytenoideus,	Superior and inferior laryngeal.
26. Thyro-epiglottideus,	Inferior laryngeal.
27. Aryteno-epiglottideus inferior,	" "
28. Aryteno-epiglottideus superior,	*Inferior laryngeal.*
29. Attollens aurem,	Occipitalis minor.
30. Attrahens aurem,	Facial or seventh.
31. Attrahens aurem,	*Posterior auricular branch of facial.*

Name.	Nervous Supply.
32. Tensor tympani,	Seventh through otic ganglion.
33. Laxator tympani (anterior ligament of the malleus),	Seventh pair.
34. Stapedius,	*Seventh pair.*
35. Levator palati,	Seventh by petrosal branches.
36. Tensor palati,	Fifth through otic ganglion.
37. Azygos uvulæ,	Descending pal. branches from Meckel's ganglion.
38. Palato-glossus,	Descending pal. branches from Meckel's ganglion.
39. Palato-pharyngeus,	*Pharyngeal P. and glosso-pharyngeal.*
40. Superior constrictor,	Pharyngeal P. and glosso-pharyngeal.
41. Middle "	
42. Inferior "	Pharyngeal P. and glosso-pharyngeal and branch ext. laryngeal.
43. Stylo-pharyngeus,	Pharyngeal P. and glosso-pharyngeal.
44. Palato-pharyngeus,	(See Fifth muscle above.)
45. Muscular fibres of œsophagus,	*Pneumogastric.*

MUSCLES ACTING ON THE OS HYOIDES, LARYNX, EYELIDS, EYEBALL, AND PERINEUM; ALSO, MUSCLES OF MASTICATION AND RESPIRATION.

1. Sterno-hyoid,	Loop from descendens and communicans noni.
2. Sterno-thyroid,	
3. Thyro-hyoid,	Hypoglossal.
4. Amo-hyoid,	Loop from descendens and communicans noni.
5. Digastric,	Fifth and seventh pair.
6. Stylo-hyoid,	Seventh pair.
7. Mylo-hyoid,	Fifth pair.
8. Genio-hyoid.	*Ninth pair.*
9. Temporal,	Fifth pair.
10. Masseter,	" "
11. External pterygoid,	" "
12. Internal "	" "
13. Buccinator,	*Buccal branch of inf. maxillary and facial.*
14. Levator palpebræ,	Third pair.
15. Orbicularis palpebrarum,	*Seventh pair.*
16. Superior rectus,	Third pair.
17. Inferior oblique,	" "

Name.	Nervous Supply.
18. Superior oblique,	Fourth pair.
19. Inferior rectus,	Third "
20. Internal "	" "
21. External rectus,	*Sixth pair.*
22. Tensor tarsi (Horner's muscle),	*Seventh pair.*
23. Diaphragm,	Phrenic nerves and phrenic plexus of sympathetic.
24. Scalenus anticus,	Lower C. nerves, ant. branches.
25. " medius,	
26. " posticus,	
27. Intercostales externi,	Ant. brs. of lower cervical nerves.
28. Levatores costarum (12 pair),	Intercostal nerves.
29. Serratus posticus superior,	Intercostal.
30. Sterno-cleido-mastoid,	Post. division of C. nerves (ext. brs.).
31. Levator anguli scapulæ,	Deep brs., C. P. and spinal accessory.
32. Trapezius,	Third and fourth cervical (inner division).
33. Pectoralis major,	Spinal accessory and third and fourth cervical (ant. division).
34. " minor,	Anterior thoracic (ext. branch), B. P.
35. Serratus magnus,	Anterior thoracic nerve (deep or int. branch , B. P.
36. Intercostales interni,	Posterior or long thoracic nerve, B. P.
37. Infracostales,	Intercostal nerves.
38. Serratus posticus inferior,	Intercostal.
39. Triangularis sterni,	Ext. branches of dorsal nerves.
40. Obliquus externus abdominis,	Intercostal.
41. " internus "	(See Transversalis.)
42. Transversalis,	" "
43. Sacro-lumbalis,	Ilio-hypogastric, ilio-inguinal, and lower intercostals.
44. Levator ani,	*L. and D.* (See Muscles acting on Spine.)
45. Accelerator urinæ,	Branch of fourth sacral and pudic nerves.
46. Erector penis,	Pudic.
47. Transversus perinæi,	"
48. Compressor urethræ,	"
49. Coccygeus,	"
	Ant. brs. of fourth and fifth sacral and coccygeal nerves.

ORIGIN OF MUSCLE.

Muscles acting on the Upper Extremity.

1. Outer border and upper surface of the outer third of the clavicle; ext. border of acromion process, and whole length of the lower border of the spine of the scapula.
2. Supraspinous fossa of scapula and aponeurosis covering the muscle.
3. Sternal half of clavicle; sternum and cartilages of the true ribs; oblique aponeurosis.
4. Dorsal aspect of axillary border and inferior angle of the scapula.
5. Spinous processes of six inferior dorsal vertebræ; spinous processes of lumbar and sacral vertebræ; three or four lower ribs and crest of ilium posteriorly.
6. Apex of the coracoid process of the scapula.
7. Infraspinous fossa of scapula and aponeurosis covering the muscle.
8. Upper two-thirds of the axillary border of the scapula, dorsal surface.
9. *Subscapular fossa and tendinous intersections.*
10. *Long head:* from the upper margin of the glenoid cavity of the head of the scapula; *Short head:* from the coracoid process of the same bone.
11. Outer and inner surfaces of the lower half of the shaft of the humerus.
12. *Middle head:* from the inferior border of the glenoid cavity; *External head:* from the external surface of the shaft of the humerus *above* the musculo-spiral groove; *Internal head:* from the internal surface of the shaft of the humerus *below* the musculo-spiral groove.
13. Back part of the external condyle of the humerus.
14. Upper two-thirds of the external condyloid ridge of the humerus.
15. External condyle; external lateral ligament of the elbow-joint; orbicular ligament for the head of the radius, and from the ulna and aponeurosis covering the muscle.
16. *First head:* from the internal condyle of the humerus and intermuscular septum; *Second head:* from the inner side of the coranoid process of the ulna.
17. *From the lower fourth of the anterior surface of the shaft of the ulna.*
18. From the internal condyle of the humerus; intermuscular septum; runs through a groove in the os trapezium.
19. Internal condyle; olecranon process; and upper two-thirds of the posterior border of the ulna.
20. Internal condyle and intermuscular septum.
21. External condyloid ridge; lower third of intermuscular septum.
22. " condyle; external lateral ligament of the elbow and intermuscular septum.
23. *External condyle; middle third of the posterior border of the ulna.*

24. Internal condyle; internal lateral ligament; intermuscular septum; coronoid process of the ulna and the oblique line of the radius.
25. Upper two-thirds of the anterior and inner surfaces and posterior border of the shaft of the ulna; coronoid process of the ulna, and ulnar half of the interosseous membrane.
26. From the flexor profundis digitorum.
27. Unciform process of the unciform bone and annular ligament of the wrist-joint.
28. External condyle of the humerus; intermuscular septum.
29. " " " " " "
30. Small part of the posterior surface of the ulna below the extensor secundi internodii pollicis muscle.
31. From the entire length of the metacarpal bone of one finger: the first, from the ulnar side of the second metacarpal bone; the second, from the radial side of the fourth metacarpal bone; the third, from the radial side of the fifth metacarpal bone.
32. Each by two heads from adjacent sides of the metacarpal bones, nearer the dorsal surface.
33. Upper two-thirds anterior surface of the radius; interosseous membrane, radial half; base of coronoid process.
34. Trapezium; two-thirds annular ligament; trapezoid; os magnum; base third metacarpal bone; sheath of the tendon of the flexor carpi radialis.
35. Trapezium and annular ligament.
36. Middle third radius, ulna, and interosseous ligament, post. surface.
37. Post. surface of radius and interosseous membrane below the extensor ossis metacarpi pollicis.
38. Post. surface of the ulna below the extensor ossis metacarpi pollicis.
39. Metacarpal bone of the middle finger.
40. Trapezium and annular ligament.
41. Pisiform bone; tendon of the flexor carpi ulnaris.
42. Unciform process of the unciform bone and annular ligament.
43. Annular ligament and palmar fascia.
44. Small origin above the oleeranon fossa of the ulna.

Muscles acting on the Lower Extremity.

1. Sides of the bodies and intervertebral substances of the twelfth dorsal vertebra and all the lumbar vertebræ.
2. Iliac fossa; crest of the ilium; ilio-lumbar ligament; base of the sacrum; capsule of the hip-joint.
3. Ilio-pectineal line and the bone in front of it.
4. Anterior superior spinous process of the ilium; anterior portion of the crest of the ilium, outer lip.

5. Superior curved line on the external surface of the ilium and the bone behind it; last piece of the sacrum; side of the coccyx; post. sacro-iliac and great sacro-sciatic ligaments.
6. Outer surface of the ilium, between the superior and middle curved lines; outer lip of the portion of the crest between these lines.
7. Surface of bone between the middle and inferior curved lines, and ant. border of the great sacro-sciatic notch.
8. Anterior surface of the pubes, near junction of the crest with the symphysis.
9. Rami of pubes and ischium; tuberosity of ischium.
10. Descending ramus of the pubes.
11. Rami of the pubes and ischium.
12. Front of the sacrum; great sacro-sciatic ligament and margin of the great sacro-sciatic foramen.
13. Inner surface of the obturator membrane and bones surrounding.
14. Inner two-thirds of outer surface of the obturator membrane and the bones surrounding this foramen.
15. Spine of the ischium (post. surface).
16. Upper border of the tuberosity of the ischium.
17. *Outer border of the tuberosity of the ischium.*
18. *Long head:* posterior portion of the tuberosity of the ischium with the semitendinosus; *Short head:* from the outer lip of the linea aspera of the femur.
19. Upper and outer portion of the tuberosity of the ischium.
20. With the *long head* of the biceps.
21. External condyle of the femur; posterior ligament of the knee-joint.
22. *First head:* anterior inferior spinous process of the ilium; *Second head:* groove above the acetabulum (*reflected*).
23. External lip of the linea aspera; trochanter major and the line between.
24. Internal lip of the linea aspera; internal, anterior, and external surfaces of the femur.
25. Same as 24.
26. *Anterior superior spinous process of the ilium, and half of the notch below it.*
27. Outer tuberosity, and upper and external two-thirds of the tibia and part of the interosseous membrane.
28. Lower fourth of the anterior surface of the fibula, and part of the interosseous membrane.
29. By two heads from the condyles of the femur and linea aspera.
30. Head and posterior and upper third of the shaft of the fibula; oblique line on the tibia, and the tendinous arch between.
31. Outer bifurcation of the linea aspera; post. lig. knee-joint.

32. Interosseous membrane; posterior and middle two-thirds of the shaft of the tibia and fibula.
33. Upper two-thirds of the outer surface of the fibula.
34. Middle third of the external surface of the fibula.
35. Posterior surface of the tibia below the oblique line.
36. Os calcis and the plantar fascia.
37. Os calcis; calcaneo-scaphoid and long plantar ligaments.
38. From tendons of the profound flexors.
39. Base of the metatarsal bone of the little toe, and sheath of the peroneus longus.
40. Outer tuberosity of the tibia; upper anterior three-fourths of the fibula and interosseous membrane.
41. Os calcis; annular ligaments and astragalo-calcanean ligament.
42. Bases and inner sides of the third, fourth, and fifth metatarsal bones.
43. Adjacent sides of metatarsal bones.
44. Anterior and middle half of the fibula and the interosseous membrane.
45. Two-thirds internal surface of the fibula and interosseous membrane.
46. Cuboid and external cuneiform bones; tendon of the tibialis posticus.
47. Tarsal extremities of second, third, and fourth metatarsal bones, and the sheath of the tendon of the peroneus longus.
48. Inner side of the head of the fifth metatarsal bone and transverse ligament of the tarsus.
49. Inner tuberosity of the os calcis; annular ligament, and plantar fascia.
50. Outer tuberosity of the os calcis and plantar fascia.
51. Anterior surface of the lower portion of the shaft of the femur.
52. Sides of last dorsal and first lumbar vertebræ.

Muscles acting on the Spine, Head, Neck, and Scapula.

1. Spinous processes of the cervical vertebræ.
2. Occur in pairs between, and unite the spinous processes of a vertebra above with the spinous process of one below. They number six pairs in the cervical region; in the dorsal region there are two and sometimes three pairs; in the lumbar region there are four pairs. Generally there is one at the beginning of the lumbar and sacral regions, making in all fifteen pairs.
3. From the spinous processes of the eleventh and twelfth dorsal, and the first and second lumbar vertebræ by three or four tendinous bands.
4. By tendinous or muscular slips, from the spinous processes of the fifth, sixth, and seventh cervical vertebræ; sometimes from the same processes of the first and second dorsal vertebræ.
5. From the spinous process of the axis.

6. By a narrow tendon from the tubercle on the posterior arch of the atlas.
7. By narrow tendinous bands from the transverse processes of the fifth, sixth, seventh, eighth, ninth, tenth, and eleventh dorsal vertebræ.
8. From the transverse processes of the first, second, third, and fourth dorsal vertebræ, and articular processes of the fourth, fifth, sixth, and seventh cervical vertebræ by small tendinous and fleshy bands.
9. Muscular and tendinous fasciculi from the sacrum as low as the fourth sacral foramen; aponeurosis of origin of the erector spinæ muscle; inner surface of the posterior superior spinous process of the ilium and posterior sacro-iliac ligaments; from the articular processes of the vertebræ in the lumbar and cervical regions, and from the transverse processes of the vertebræ in the dorsal region.
10. Upper and posterior part of the transverse processes of the dorsal vertebræ. This muscle is covered by the multifidus spinæ.
11. From the apex of the spinous process of the axis.
12. Transverse processes of the vertebræ. There are seven pairs in the cervical region, twelve in the dorsal region, and four in the lumbar region.
13. Transverse processes of the upper three dorsal vertebræ, and seventh cervical vertebra; articular processes of the fourth, fifth, and sixth cervical vertebræ.
14. From the transverse processes of the upper three or four dorsal vertebræ by from two to four tendinous bands.
15. *Upper part of the transverse process of the atlas.*
16. From the crest and symphysis pubis.
17. Outer half of Poupart's ligament; anterior two-thirds of the middle portion of the crest of the ilium, and from the lumbar fascia (posterior lamella).
18. From the external surface of the eight inferior ribs near the cartilages.
19. Extend between adjacent ribs, inner borders.
20. " " " " outer "
21. *Superior portion:* from the anterior tubercles of the transverse processes of the third, fourth, and fifth cervical vertebræ; *Inferior portion:* from the bodies of the first, second, and third dorsal vertebræ; *Vertical portion:* from the bodies of the lower three cervical vertebræ and upper three dorsal vertebræ.
22. Tubercle of the first rib.
23. Back part of the inner lip of the crest of the ilium; sacro-sciatic ligament; sacro-iliac groove; spinous and transverse processes of the sacrum; spinous processes of the lumbar and three or four of the dorsal vertebræ, and supraspinous ligament.
24. Continuation of the erector spinæ.

25. From the angles of the six inferior ribs.
26. " " " four or five upper ribs.
27. Continuation of the erector spinæ.
28. From the transverse processes of the third, fourth, fifth, and sixth dorsal vertebræ.
29. From the transverse processes of the third, fourth, fifth, and sixth dorsal vertebræ, and from the articular processes of the three or four lower cervical vertebræ.
30. Spinous processes of the six inferior dorsal vertebræ; spinous processes of the lumbar and sacral vertebræ; supraspinous ligament; crest of the ilium behind the external oblique muscle; three or four inferior ribs.
31. *Ilio-lumbar ligament; posterior two inches of the iliac crest; transverse processes of the third, fourth, and fifth lumbar vertebræ.*
32. Anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ.
33. Lateral mass of the atlas and root of its transverse process.
34. Inner third of the superior curved line of the occipital bone; ligamentum nuchæ; spinous processes of the seventh cervical and all the dorsal vertebræ.
35. Lower half of the ligamentum nuchæ; spinous processes of the seventh cervical and six upper dorsal vertebræ; supraspinous ligament.
36. Same as 35.
37. Upper surfaces of the first rib, external to or behind the groove for the subclavian artery.
38. Outer surface of the second rib, behind the serratus magnus muscle.
39. Posterior tubercles of the transverse processes of the three or four upper cervical vertebræ.
40. Manubrium or first piece of the sternum, and the inner third of the superior border of the clavicle.
41. *Upper surface of the transverse process of the atlas.*
42. Upper margin and outer surface of the third, fourth, and fifth ribs near the cartilages.
43. Outer surfaces and upper borders of the eight superior ribs, the second rib having two serrations; aponeurosis over the intercostal spaces.
44. Spinous processes of the four or five upper dorsal vertebræ and the supraspinous ligament.
45. Ligamentum nuchæ; spinous processes of the seventh cervical and first dorsal vertebræ.
46. *Cartilage of the first rib.*
47. Front of os pubis and anterior pubic ligament.
48. *Outer third of Poupart's ligament; anterior three-fourths of the inner lip of the crest of the ilium; inner surface of the cartilages of the six lower*

ribs; and by an aponeurosis from the spinous and transverse processes of the lumbar vertebræ.

MUSCLES ACTING ON THE EXTERNAL EAR, TYMPANUM, AND SOFT PALATE; ALSO, MUSCLES OF EXPRESSION, PHONATION, AND DEGLUTITION.

1. From the clavicle and acromion process of the scapula; fascia over the pectoral, deltoid, and trapezius muscles.
2. Inner extremity of the superciliary ridge.
3. Continuous with the median portion of the occipito-frontalis muscle.
4. Nasal process of the superior maxillary bone.
5. Nasal notch of the superior maxillary bone and sesamoid cartilages.
6. Cartilage of the alæ (wings of the nose).
7. Superior maxillary bone external to the incisive fossa.
8. Alar cartilage.
9. Incisive fossa of the superior maxillary bone.
10. Lower margin of the orbit.
11. Canine fossa of the superior maxillary bone.
12. Malar bone anterior to the zygomatic suture.
13. " " posterior to the maxillary suture.
14. Incisive fossa of the inferior maxillary bone.
15. External oblique line of the inferior maxillary bone between the symphysis and mental foramen.
16. External oblique line of the inferior maxillary bone posterior to the mental foramen.
17. Alveolar process of the superior and inferior maxillary bones as far forward as the first molar tooth; anterior border of the pterygo-maxillary ligament.
18. Masseteric fascia (that part of the deep cervical fascia which covers the masseter muscle).
19. Surrounds the mouth in an elliptic form. *Labial or marginal fibres:* encircle the mouth, and the fibres above decussate with the fibres below at the angles of the mouth; *Facial fibres:* some (central) fibres decussate at the angles of the mouth, the superior and inferior fibres becoming directly continuous with the buccinator muscle; *Superior accessory bands:* from superior maxillary bone external to the incisive fossa; *Naso-labial slips:* septum nasi, limiting the philtrum; *Inferior accessory bands:* from the inferior maxillary bone external to the levator menti or levator labii inferioris.
20. *Occipital portion:* from the external two-thirds of the superior curved line of the occipital bone; mastoid process of the temporal bone;

Frontal portion: from the aponeurosis uniting the two bellies of the muscle.

21. Front and side of the cricoid cartilage.
22. Lateral half of the posterior surface of the cricoid cartilage.
23. Superior border of the side of the cricoid cartilage.
24. Receding of the thyroid cartilage and the crico-thyroid membrane.
25. Posterior surface and outer border of one arytenoid cartilage external to the thyro-arytenoid muscle.
26. Inner surface of one thyroid cartilage.
27. Anterior surface of the arytenoid cartilage above the vocal cord.
28. *Apex of arytenoid.*
29. Aponeurosis of the occipito-frontalis muscle.
30. Lateral edge of the aponeurosis of the occipito-frontalis muscle.
31. *Mastoid process of the temporal bone.*
32. Inferior surface of the petrous portion of the temporal bone, and the cartilaginous portion of the Eustachian tube and bony canal in which it runs.
33. Anterior wall of the tympanum near the Glasserian fissure (and by some fibres from the spinous process of the sphenoid bone and cartilaginous portion of the Eustachian tube, Bryant). This muscle, so called by Sömmering, is thought to be composed of ligamentous fibres only, and should not be classified as one of the muscles of the tympanum.
34. *From a conical cavity within the eminentia pyramidalis.*
35. Under surface of the apex of the petrous portion of the temporal bone, and the cartilaginous portion of the Eustachian tube.
36. Vaginal process of the temporal bone; spine of the sphenoid bone; cartilaginous part of the Eustachian tube; scaphoid fossa at the base of internal pterygoid plate of the pterygoid process of the sphenoid bone.
37. Posterior nasal spine of the palate bone.
38. Anterior surface of the soft palate.
39. *Posterior surface of the soft palate by two fasciculi.*
40. Lower third of the posterior margin of the internal pterygoid plate; its hamular process; palate bone; reflected tendon of the tensor palati; pterygo-maxillary ligament; alveolar process of inferior maxillary bone above the post. extremity of the mylo-hyoid ridge; side of the tongue with the genio-hyoglossus muscle.
41. Greater and lesser cornua of the hyoid bone and the stylo-hyoid ligament.
42. Thyroid and cricoid cartilages.
43. Base of the styloid process of the temporal bone, inner surface.
44. Same as 39.

45. Cricoid cartilages and inferior constrictor muscle of the pharynx.

MUSCLES ACTING ON THE OS HYOIDES, LARYNX, EYELIDS, EYEBALL, AND PERINEUM; ALSO, MUSCLES OF MASTICATION AND RESPIRATION.

1. Inner extremity of the clavicle; upper part of posterior surface of the first piece of the sternum.
2. First piece of the sternum below the preceding muscle, occasionally from the edge of the cartilage of the first rib.
3. Oblique line on the thyroid cartilage; this muscle is an apparent continuation of the sterno-thyroid.
4. Upper border of the scapula and transverse ligament held by a strip of the deep cervical fascia to the cartilage of the first rib and sternum.
5. Digastric groove in mastoid process of the temporal bone (*posterior belly*); depression on the inner surface of the lower jaw external to the symphysis (*anterior belly*). The two bellies unite to form a central tendon.
6. Near the base of the styloid process of the temporal bone, external surface.
7. Whole length of the mylo-hyoid ridge, extending from the symphysis to the last molar tooth.
8. *Inferior genial tubercle.*
9. Temporal fossa, except the part formed by the malar bone; inner surface of the temporal fascia.
10. *Superficial portion:* malar process of the superior maxillary bone; anterior two-thirds of the inferior border of the zygomatic arch; *Deep portion:* poster. third of the inferior border of the zygomatic arch, and the whole of the inner surface of this arch.
11. Pterygoid ridge on the great wing of the sphenoid bone, and the bone between this ridge and the base of the pterygoid process; external surface of the external pterygoid plate.
12. Pterygoid fossa; attached to the internal surface of the external pterygoid plate; groove of the tuberosity of the palate bone; tuberosities of plate and superior maxillary bones.
13. See above.
14. Inferior surface of the lesser wing of the sphenoid bone in front of the optic foramen.
15. *Internal angular process of the frontal bone; nasal process of the superior maxillary bone, anterior to the lachrymal groove; tendo oculi or tendo palpebrarum.*
16. Upper margin of the optic foramen, and the sheath of the optic nerve.
17. Orbital plate of the sup. max. bone ext. to the lachrymal groove.

18. About one line above the inner margin of the optic foramen (passes through a pulley at the inner angle of the orbit).
19. Ligament of Zinn (or tendon or aponeurosis of Zinn).
20. Ligament of Zinn.
21. *First head:* outer margin of the optic foramen; *Second head:* ligament of Zinn, and lower margin of the sphenoidal fissure.
22. *Crest and adjacent orbital surface of the lachrymal bone.*
23. Ensiform cartilage; cartilage and bony parts of the six or seven inferior ribs; ligamentum arcuatum internum and externum to the second, third, and fourth lumbar vertebræ on the right side, and to the second and third l. v. on the left side.
24. By a narrow tendon from the tubercle of the first rib, situated on the inner border of its superior surface. This tendon separates two important grooves on the upper surface of the first rib. The anterior one transmits the subclavian vein, the posterior the subclavian artery with the brachial plexus of nerves.
25. Upper surface of the first rib, between the groove for the subclavian artery in front and the tubercle of the rib behind.
26. By a delicate tendinous strap, from the outer surface of the second rib posterior to the attachment of the serratus magnus muscle.
27. External lip of the groove on the inferior border of each rib. These muscles extend from the tubercles of the ribs behind to the beginning of the costal cartilages in front.
28. Extremities of the transverse processes of the seventh cervical and eleventh superior dorsal vertebræ.
29. Ligamentum nuchæ; spinous processes of the seventh cervical and the first, second, and third dorsal vertebræ.
30. *Sternal portion:* from the upper and front part of the first piece of the sternum; *Clavicular portion:* inner third of the superior border of the clavicle. (This origin varies in extent.)
31. By tendinous slips from the posterior tubercles of the transverse processes of the first, second, third, fourth, and fifth cervical vertebræ.
32. Spinous processes of all the dorsal and the seventh cervical vertebræ; ligamentum nuchæ; internal third of the superior curved line of the occipital bone; supraspinous ligament.
33. Sternal half of the clavicle, ant. surface; half the breadth of the ant. surface of the sternum as far down as the cartilage of the sixth or seventh rib; from the cartilages of the seven upper ribs (except, occasionally, that of the first and seventh); aponeurosis of the external oblique muscle of the abdomen.
34. Upper margins and external surfaces of the third, fourth, and fifth ribs, near their anterior extremities; aponeurosis covering the intercostal muscles.

35. By nine muscular digitations, from the external surfaces and superior borders of the eight superior ribs (second rib having two slips); the aponeurosis covering the superior intercostal spaces.
36. Internal lip of the groove on the inferior border of each rib and the corresponding costal cartilage. These muscles extend from the sternum in front to the angles of the ribs behind, where they become aponeurotic and are attached to the corresponding vertebræ.
37. Inner surface and side of one rib.
38. Spinous processes of the eleventh and twelfth d. v. and two or three upper lumbar vertebræ.
39. Lower part of the gladiolus; ensiform cartilage; costal cartilages of the three or four lower true ribs.
40. By eight fleshy digitations, from the outer surfaces and inferior borders of the eight lower ribs. (The five upper serrations of this muscle interdigitate with the corresponding processes of the serratus magnus, the three lower ones with those of the latissimus dorsi muscle.)
41. Outer half of upper part of Poupart's ligament; anterior two-thirds of the middle lip of the crest of the ilium; posterior layer of the lumbar fascia.
42. Outer third of Poupart's ligament by fleshy fibres; anterior three-fourths of the inner lip of the crest of the ilium; internal surface of the cartilages of the six inferior ribs; spinous and transverse processes of the lumbar vertebræ.
43. *Is the external portion of the erector spinæ, called also the ilio-costalis.*
44. Posterior surface of the body and ramus of the pubes; spine of the ischium; junction of the obturator and ischio-rectal fasciæ.
45. Central tendon of the perineum and median raphé.
46. Inner surface of the tuberosity of the ischium behind the crus penis; surface of the crus and ramus of the pubes.
47. Inner and fore side of the tuberosity of the ischium.
48. Upper part of the ramus of the pubes.
49. Spine of the ischium and lesser sacro-sciatic ligament.

INSERTION OF MUSCLE.

Muscles acting on the Upper Extremity.

1. Middle of the humerus externally.
2. Anterior facet on the greater tuberosity of the humerus.
3. Anterior bicipital ridge of the humerus.
4. Posterior " " " "
5. Bicipital groove of the humerus and internal bicipital ridge.

6. Middle of the shaft of the humerus internally.
7. Middle facet of the great tuberosity of the humerus.
8. Posterior " " " " " "
9. *Lesser tuberosity of the humerus.*
10. Back part of the tuberosity of the radius continuous with the fascia of the forearm.
11. Base of the coronoid process of the ulna.
12. Back portion of the olecranon process of the ulna continuous with the fascia of the forearm.
13. Side of the olecranon process and upper fourth of the posterior surface of the ulna.
14. Styloid process of the radius.
15. Back part of the inner surface of the radius above the tuberosity; outer edge of the bicipital tuberosity and oblique line of the radius to the insertion of the pronator radii teres.
16. Middle of the outer surface of the shaft of the radius.
17. *Lower fourth of the external border of the shaft of the radius.*
18. Base of the metacarpal bone of the index finger.
19. Pisiform bone and annular ligament of the wrist.
20. Annular ligament and palmar fascia.
21. Base of the metacarpal bone of the index finger, radial side.
22. " " " " " middle " " "
23. *Base of the metacarpal bone of the little finger.*
24. Middle of the second phalanges, palmar surface, and lateral margins; with the first phalanges by the *vincula accessoria tendinum.*
25. Bases of the third phalanges.
26. Dorsum of the first phalanges into the extensor tendons.
27. Base of the first phalanx of the little finger.
28. Second and third phalanges, base and dorsal surface.
29. " " " of the little finger.
30. " " " of the index "
31. Base of the first phalanges of the first, third, and fourth fingers, and common extensor tendon of the same fingers.
32. *Base of the first phalanges, and extensor tendons of the index, middle, and ring fingers.* (*The second and third are inserted into the middle finger.*)
33. Base of the last phalanx of the thumb.
34. Each side of the base of the first phalanx of the thumb.
35. To the whole length of the metacarpal bone of the thumb, radial side.
36. Base of the metacarpal bone of the thumb.
37. " " first phalanx " "
38. " " last " " "
39. Ulnar side of the base of the first phalanx of the thumb and internal sesamoid bone.

40. Radial side of the base of the first phalanx of the thumb.
41. Base of the first phalanx of the little finger, ulnar side.
42. Whole length of the metacarpal bone of the little finger.
43. To the skin on the inner border of the palm.
44. Posterior ligament of the elbow-joint.

Muscles acting on the Lower Extremity.

1. Lesser trochanter of the femur.
2. Lesser trochanter and the line below.
3. Line between the trochanter minor and linea aspera.
4. Fascia lata, outer side, one-fourth down the thigh.
5. Fascia lata, and a line leading from the trochanter major to the linea aspera.
6. Oblique line on the outer surface of the great trochanter.
7. Anterior border of the great trochanter.
8. Middle third of the linea aspera.
9. Whole length of the linea aspera, and the tubercle of the inner condyle of the femur.
10. Upper part of the linea aspera.
11. Inner surface of the shaft of the tibia below the tuberosity.
12. Great trochanter, upper border.
13. " " " "
14. Digital fossa of the femur.
15. Blends with and is inserted with the obturator internus.
16. " " " " " " "
17. Linea quadrati.
18. Head of the fibula; external tuberosity of the head of the tibia; also, continuous with the fascia of the leg.
19. *Middle portion:* inner tuberosity of the tibia, and extending ontward forms the popliteal fascia; *Internal portion:* to the inner tuberosity; *Posterior portion:* inner tuberosity, and extending to the outer condyle of the femur forms the oblique portion of the ligamentum posticum Winslowii.
20. Upper and inner surface of the tibia beneath the sartorius muscle.
21. Triangular surfaee above the oblique line on the tibia.
22. Joins the quadriceps tendon, which has the patella developed within it and is inserted into the tuberosity of the tibia.
23. Blends with the quadrieeps extensor muscle.
24. " " " " "
25. " " " " "
26. Upper and inner surface of the shaft of the tibia in front of the semitendinosus and gracilis muscles.

27. Inner and under surface of the cuneiform bone, and base of the metatarsal bone of the great toe.
28. Base of the metatarsal bone of the little toe, inner side.
29. Assists in forming the tendo Achillis, which is inserted into the posterior inferior surface of the os calcis, blending with the periosteum.
30. Joins in forming the tendo Achillis.
31. Inserted with the tendo Achillis.
32. Tuberosity of the tarsal scaphoid, internal cuneiform, and by a fibrous expansion into the os calcis, middle and external cuneiform, and the third and fourth metatarsal bones.
33. Running through the calcaneo-cuboid groove is inserted on the outer side of the base of the metatarsal bone of the great toe.
34. Base of the metatarsal bone of the little toe, outer side of dorsal surface.
35. Bases of the last phalanges of the four lesser toes.
36. Each side of the second phalanges.
37. Outer margin and surface of the tendon of the flexor longus digitorum.
38. Expansion of long extensor or dorsum of the phalanges.
39. Base of first phalanx, outer side.
40. Bases of second and third phalanges of the four lesser toes.
41. The innermost tendon into the first phalanx of the great toe, the others into the long extensor tendons, dorsal surface, outer side.
42. Base of first phalanges and extensor tendons, inner side.
43. Base of first phalanges and extensor tendons, outer side, except the first, which is in the inner side.
44. Base of the last phalanx of the great toe.
45. Last phalanx of the great toe, under surface.
46. *Two heads:* base of first phalanx, each side.
47. Outer side of the first phalanx of the great toe, joining with the outer head of flexor brevis pollicis.
48. Outer side of the first phalanx, blending with the former.
49. Base of first phalanx, inner side.
50. Base of first phalanx of the little toe, outer side.
51. Upper part of the synovial pouch of the knee.
52. Pectineal eminence and iliac fascia.

MUSCLES ACTING ON THE SPINE, HEAD, NECK, AND SCAPULA.

1. As classified under Function.
2. " " " "
3. " " " "
4. " " " "
5. Inferior curved line of the occipital bone.

6. Occipital bone below the inferior curved line.
7. As classified under Function.
8. " " " "
9. " " " "
10. " " " "
11. Apex of the transverse process of the atlas.
12. As classified under Function.
13. Between the superior and inferior curved lines of the occipital bone.
14. As classified under Function.
15. *Occipital bone between the superior and inferior curved lines.*
16. Cartilages of the fifth, sixth, and seventh ribs.
17. Crest of the os pubis and pectineal line, linea alba, cartilages of the four lower ribs.
18. Spine of pubes, Poupart's ligament, pectineal line, linea alba, anterior half of the outer lip of the crest of the ilium.
19. *Internal:* from the sternum to the angles of the corresponding ribs.
20. *External:* from the tubercles of the corresponding ribs to the costal cartilages.
21. *Superior portion:* tubercle on the anterior arch of the atlas; *Inferior portion:* anterior tubercles of the transverse processes of the fifth and sixth cervical vertebræ; *Vertical portion:* bodies of second, third, and fourth cervical vertebræ, anterior surfaces.
22. Anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ.
23. As given under Function.
24. Angles of the six inferior ribs.
25. " " superior "
26. Posterior tubercles of the transverse processes of the fourth, fifth, and sixth cervical vertebræ.
27. From articular and transverse processes of l. v. tips of transverse processes of the d. v., lumbar fascia, and seven to eleven ribs near the angles.
28. Posterior tubercles of the transverse processes of the lower five cervical vertebræ.
29. Posterior margin of the mastoid process of the temporal bone beneath the sterno-cleido-mastoid muscle.
30. Bicipital groove of the humerus and inner lip of this groove.
31. Lower border of last rib (half its length), and into the apices of the transverse processes of the first, second, third, and fourth lumbar vertebræ (*First portion*); *Second portion:* into the inferior border of the twelfth rib.
32. Basilar process of the occipital bone.
33. " " " " " behind the former.

34. Posterior border of the outer third of the clavicle, inner margin of the acromion process, superior lip of the spine of the scapula by a triangular aponeurosis into the tubercle of the spine.
35. Occipital bone below the superior curved line, and mastoid process of the temporal bone.
36. Post. tubercles of the transverse processes of the three or four upper c. v.
37. Post. tubercles of the transverse processes of the six lower c. v.
38. Post. tubercles of the transverse processes of the fifth, sixth, and seventh c. v.
39. Post. border of the scapula between the superior angle and the root of the spine.
40. Outer surface of the mastoid process of the temporal bone, and outer third of the superior curved line of the occipital bone.
41. *Under surface of the jugular process of the occipital bone.*
42. Anterior border of the coracoid process of the scapula.
43. Whole length of the posterior border of the scapula, anterior margin or surface.
44. Ligamentous arch on the post. border of the scapula, extending from the base of the spine to the inferior angle.
45. Root of the spine of the scapula.
46. *Under surface of the middle third of the clavicle.*
47. Contained within the sheath of the rectus abdominis, into which it is inserted midway between the umbilicus and pubes.
48. *Crest of the pubes, pectineal line, and linea alba.*

MUSCLES ACTING ON THE EXTERNAL EAR, TYMPANUM, AND SOFT PALATE; ALSO, MUSCLES OF EXPRESSION, PHONATION, AND DEGLUTITION.

1. Inf. maxillary bone beneath the external oblique line, cellular tissue of the face blends with its fellow of the opposite side, and with three or four facial muscles.
2. Orbicularis palpebrarum.
3. Blends with the compressor nasi.
4. Cartilage of the alæ of the nose and upper lip.
5. The skin near the margin of the nostril.
6. Integument at its margin.
7. Fibro-cartilage, its fellow of the opposite side, and the aponeurosis of the pyramidalis.
8. Integument at the end of the nose.
9. Septum and back part of alæ.

10. Upper lip.
11. Angle of the mouth.
12. " " "
13. " " "
14. Integument of the chin.
15. Lower lip.
16. Angle of the mouth.
17. The highest and lowest fibres do not decussate, but are continued forward into the corresponding segment of the lip; the central fibres decussate with each other: those from below running into the upper segment of the orbicularis, those from above running into the lower segment of the same muscle.
18. Angle of the mouth.
19. Joins with the muscles passing to the lips.
20. *Blends with the muscles of the palpebral and nasal regions, and to the nasal bone and ext. angular process of the frontal bone* (Theile).
21. Lower border of the thyroid cartilage from the median line to the inferior cornu.
22. Outer angle of the base of the arytenoid cartilage.
23. " " " " " " "
24. Base and anterior surface of the arytenoid cartilage.
25. To corresponding part of the other.
26. Margin of the epiglottis and aryteno-epiglottidean fold.
27. Margin of the epiglottis.
28. *Aryteno-epiglottidean fold.*
29. Pinna, cerebral surface.
30. Helix, anterior part.
31. *Concha, cranial, and lower surface.*
32. Handle of the malleus near its root.
33. Neck of the malleus above the processus gracilis.
34. *Neck of the stapes.*
35. Posterior surface of the soft palate.
36. Median line with its fellow of the opposite side, anterior surface of the soft palate, and the ridge on the posterior part of the inferior surface of the horizontal plate of the palate bone.
37. Uvula.
38. Side and dorsum of the tongue, blending with the stylo-glossus, hyo-glossus, and lingualis.
39. *Posterior border of the thyroid cartilage, with the stylo-pharyngeus, side of the pharynx, and the post. median line.*
40. Spine on the basilar process of the occipital bone and median raphé.
41. Median raphé, *overlaps the superior constrictor of the pharynx.*
42. Median raphé, overlaps the middle constrictor of the pharynx.

43. Post. border of the thyroid cartilage blending with the constrictor and palato-pharyngeus muscles.
44. Same as 39.
45. Continued upon the stomach.

MUSCLES ACTING ON THE OS HYOIDES, LARYNX, EYELIDS, EYEBALL, AND PERINEUM; ALSO, MUSCLES OF MASTICATION AND RESPIRATION.

1. Lower border of the body of the os hyoides.
2. Oblique line on the alæ of the thyroid cartilage.
3. Lower border of the body and greater cornu of the hyoid bone.
4. Lower border of the body of the hyoid bone external to the sterno-hyoid muscle.
5. Inner surface of the lower jaw near the symphysis.
6. Junction of the body and greater cornu of the hyoid bone above the omo-hyoid muscle.
7. Body of the hyoid bone and median raphé in front; the post. fibres find an attachment to the os hyoides; the middle and ant. fibres decussate in the median line, completing the floor of the mouth.
8. *Anterior surface of the body of the hyoid bone.*
9. Inner surface, apex, and anterior border of the coronoid process of the inf. maxillary bone as far forward as the last molar tooth.
10. *Superficial portion:* lower half of the external surface of the ramus of the inf. maxillary bone, and angle of the lower jaw; *Deep portion:* upper half of the external surface of the ramus, and outer surface of the coronoid process.
11. Depression on the antero-internal surface of the neck of the condyle of the inferior maxillary bone and interarticular cartilage.
12. Lower part of the inner surface of the ramus and angle of the jaw.
13. Same as given above.
14. Anterior surface of the upper tarsal cartilage.
15. Spreading over the temple and part of the cheek, it becomes blended with the corrugator supercilii and occipito-frontalis muscles. That portion of the muscle bordering the palpebral slit or fissure (orbicularis ciliaris) is inserted at the external part of the eye into a cellular raphé, external tarsal ligament, and malar bone. The orbicular portion (orbicularis latus) forms a complete ellipse.
16. Sclerotic three or four lines from the cornea.
17. Sclerotic between the superior and external recti midway between the cornea and optic nerve.
18. Sclerotic coat midway between the cornea and optic nerve between the superior and external recti.
19. Sclerotic three or four lines from the cornea.

20. Sclerotic three or four lines from the cornea.
21. *Sclerotic three or four lines from the cornea.*
22. *Tarsal cartilages near the puncta lachrymalia.*
23. Tendinous leaflets.
24. See Muscles acting on the Spine.
25. See Muscles acting on the Head and Neck.
26. " " " " " "
27. See Muscles acting on the Spine.
28. Upper surface of the rib below them between the tubercle and angle.
29. Upper borders of the second, third, fourth, and fifth ribs, a little beyond the angles.
30. See Muscles acting on the Head and Neck.
31. " " " " " "
32. " " " " " "
33. See Muscles acting on the Humerus.
34. See Muscles acting on the Scapula.
35. " " " " "
36. See Muscles acting on the Spine.
37. Inner surface of the first, second, or third rib below.
38. Lower borders of four lower ribs, a little beyond the angles.
39. Lower border and inner surface of the costal cartilages of the second, third, fourth, and fifth ribs.
40. See Muscles acting on the Spine.
41. " " " " "
42. With the internal oblique into the pectineal line, and crest of the os pubis forming the conjoined tendon, the remainder of the muscle by its aponeurosis into the linea alba.
43. *Ilio-costalis into the angles of the six or seven lower ribs by delicate flat tendons; the musculus accessorius ad sacro-lumbalem into the angles of the six upper ribs by tendons; cervicalis ascendens or descendens, a continuation of the former portion inserted into the posterior tubercles of the transverse processes of the fourth, fifth, and sixth cervical vertebræ by tendinous slips.*
44. Sides and apex of the coccyx, sides of the rectum blending with the sphincter muscles; many of the anterior fibres blend with each other (some of these pass under the prostate body).
45. *Post. fibres:* ant. surface of the triangular ligament; *Middle fibres:* surround the bulb and adjacent part of the corpus spongiosum, and join with fibres of the opposite side on the upper part of the corpus spongiosum; *Ant. fibres:* sides of corpus cavernosum passing over the dorsal veins of the penis.
46. Side and under surface of crus penis.

47. Tendinous centre of the perineum.
48. Surrounds the urethra from the prostate gland to the bulb, uniting above and below by means of a tendinous raphé.
49. Margin of the coccyx and last piece of the sacrum.

FUNCTIONS OF MUSCLES.

Muscles acting on the Upper Extremity.

1. } **Humerus**: Elevation, depression, ant. and post. movements, ext.
2. } and int. rotation, and circumduction.
3. Elevators: Deltoid, supraspinatus.
4. Depressors: Gravity, pect. major, teres major, and latissimus dorsi.
5. Anterior movement: Coraco-braehialis, pectoralis major, teres major, latissimus dorsi.
6. Posterior movement: Coraco-brachialis, pectoralis major, teres major, latissimus dorsi.
7. External rotators: Infraspinatus, teres minor.
8. Internal " Subscapularis, latissimus dorsi, teres major.
9. } Circumduction: *By a serial action of all the muscles around the*
10. } *joint.*
11. **Forearm**: Flexion, extension, supination, and pronation.
12. Flexors: Biceps, brachialis anticus.
13. " " " "
14. Extensors: Triceps, anconeus.
15. Supinators: Supinator longus, supinator brevis, biceps.
16. " " " " " "
17. Pronators: *Pronator radii teres, pronator quadratus.*
18. **Carpus**: Flexion, extension, and adduction.
19. Flexors: Flex. carpi radialis, flex. carpi ulnaris, palmaris longus.
20. " " " " " " " " " "
21. Extensors: Extensor carpi radialis longior, extensor carpi radialis
22. brevior, extensor carpi ulnaris.
23. Adductors: *Flex. carpi ulnaris, extensor carpi ulnaris.*
24. Digits: Flexion, extension, abduction, adduction.
25. Flexors: Flex. sublimis digitorum, flex. profundus digitorum, lum-
26. bricales, flex. brevis minimi digiti.
27. Extensors: Ext. communis digitorum, ext. minimi digiti, extensor
28. indicis.
29. Adductors: Palmar interossei.
30. " " "
31. " " "
32. Abductors: *Dorsal interossei.*

33. **Thumb**: Flexion, extension, abduction, adduction, circumduction
34. (opposes the fingers).
35. Flexors: Flex. longus pollicis, flex. brevis pollicis, opponens pol-
36. licis.
37. Extensors: Extensor ossis metacarpi pollicis, ext. primi internodii pollicis, ext. secundi internodii pollicis.
38. Adductor: Adductor pollicis.
39. Abductor: Abductor pollicis (opposes by the opponens pollicis or flexor ossis metacarpi pollicis).
40. Circumduction (*by action of all the muscles*).
41. **Little finger**: *additional.*
Abductor: Abductor minimi digiti.
42. Opposing: *Opponens minimi digiti.*
43. **Tensor palmar fascia**: Palmaris brevis, *deepens the palm.*
44. **Tensor of synovial pouch of elbow**: Subanconeus.

Muscles acting on the Lower Extremity.

1. **Thigh**: Flexion, extension, abduction, adduction, circumduction,
2. external and internal rotation.
3. Flexors: Psoas magnus, iliacus and pectineus (*outward tendency to*
4. *thigh*), tensor vaginæ femoris.
5. Extensors: Gravity (*when erect*), inferior fibres of the gluteus
6. maximus.
7. Abductors: Gluteus maximus, gluteus medius, gluteus minimus, ten-
8. sor vaginæ femoris.
9. Adductors: Adductor longus, adductor magnus, adductor brevis,
10. gracilis.
11. }
12. } Ext. rotators: Pyriformis, obturator internus, obturator externus,
13. } gemellus superior, gemellus inferior, quadratus femoris.
14. }
15. } Int. rotators: Gluteus medius (*anterior fibres*), gluteus minimus (*ante-*
16. } *rior fibres*), *tensor vaginæ femoris.*
17. }
18. **Leg**: Flexion, extension, adduction, internal and external rota-
19. tion.
20. Flexors: Biceps, semimembranosus, semitendinosus, popliteus.
21. Extensors: *Quadriceps extensors:* rectus femoris, vastus externus, vas-
22. tus internus, crureus.
23. Adductors: Sartorius, gracilis.
24. Internal rotators: Popliteus, semimembranosus.
25. }
26. } External " Biceps.

27. **Tarsus**: Flexion and extension.
28. Flexors: Tibialis anticus, peroneus tertius.
29. 30. 31. 32. 33. *34.* Extensors: Gastrocnemius, soleus, plantaris, tibialis postieus (*inward tendency*), peroneus longus (*outward tendency*), peroneus brevis.
35. **Toes**: Flexion, extension, adduction, abduction.
36. 37. 38. Flexors: Flexor longus digitorum, flexor brevis digitorum, flexor accessorius, lumbricales, flexor brevis minimi digiti.
39. Extensors: Extensor longus digitorum, extensor brevis digitorum.
40. Adductor: Plantar interossei.
41. 42. *43.* Abductor: Dorsal interossei.
44. **Great toe**: Flexion, extension, abduction, adduction.
45. Extensor: Extensor proprius pollicis.
46. Flexors: Flexor longus pollicis, flexor brevis pollicis.
47. Adductors: Adductor pollicis, transversus pedis.
48. *49.* Abductor: Abductor pollicis.
50. **Little toe additional**: *'additional:* Abduction, abductor minimi digiti.
51. **Tensor synovial pouch of knee**: Subcrureus.
52. Tensor of iliac fascia: *Psoas parvus.*

Muscles acting on the Spine, Head, Neck, and Scapula.

1. 2. 3. Before the spine can be acted upon as a whole, the prominent parts of the vertebræ are bound together as follows:
4. **Spinous processes to each other by the** Supraspinales, interspinales, spinalis dorsi, and spinalis colli.
6. **Spinous processes with the laminæ by the** Rectus capitis postieus major and the rectus capitis postieus minor.
7. 8. 9. **Spinous processes with the transverse processes by the** Semispinalis dorsi, semispinalis colli, multifidus spinæ, rotatores spinæ, and obliquus inferior.
10. 11. **Transverse processes with each other by the** Intertransversales.

12. 13. 14. 15. **Transverse processes and laminæ by the** *Complexus, biventer cervices, and obliquus superior.*

16. **Spine**: Flexion, extension, lateral motion, and rotation.

17. 18. 19. 20. 21. *Flexors acting together:* Rectus abdominis, obliquus internus, obliquus externus, intercostales interni, intercostales externi, rectus capitis anticus major, rectus capitis anticus minor, longus colli, scalenus anticus, and gravity.

22. 23. 24. 25. 26. 27. *Extensors acting together:* Erector spinæ; *outer mass:* sacro-lumbalis, musculus accessorius, cervicalis ascendens; *inner mass:* longissimus dorsi, transversalis colli, trachelo-mastoid, semispinalis dorsi, semi-spinalis colli, multifidus spinæ, rotatores spinæ.

28. 29. *Lateral flexors:* Latissimus dorsi, quadratus lumborum, gravity.

30. 31. *Rotators:* Principally by the muscles connecting the transverse and spinous processes.

32. 33. **Head and Neck**: Flexion, extension, lateral flexion, rotation.

34. *Flexors:* Rectus capi. anti., major and minor, longus colli.

35. 36. 37. *Extensors:* Trapezius, complexus, splenius capitis, splenius colli, rectus capitis posticus minor, and obliquus capitis superior.

38. 39. 40. *Lateral flexors:* Scalenus anticus, medius, and posticus, levator anguli scapulæ, sterno-cleido-mastoid, and rectus lateralis.

41. *Rotators:* Sterno-cleido-mastoid, obliquus capitis inferior and superior, and rectus capitis posticus major.

42. 43. **Scapula**: Ant. post. upward, downward, and rotatory movements.

44. *Ant. movement:* Pectoralis minor, serratus magnus.

45. 46. *Posterior movement:* Rhomboideus major, rhomboideus minor, and the middle and inferior fibres of the trapezius.

Upward movement: Levator anguli scapulæ, and middle and upper fibres of trapezius.

Downward movement: Gravity, latissimus dorsi, and subclavius.

Rotation: This movement is produced by the lower fibres of the serratus magnus drawing the anterior border and angle of the bone forward and upward, thereby changing the direction of the glenoid

cavity, which is a fact of importance surgically. This motion also increases the availability of the humeral movements.

47. **Tensor of the sheath of the rectus abdominis**: Pyramidalis.
48. **Compressor of the abdominal contents**: Transversalis.

MUSCLES ACTING ON THE EXTERNAL EAR, TYMPANUM, AND SOFT PALATE; ALSO, MUSCLES OF EXPRESSION, PHONATION, AND DEGLUTITION.

1–*20. Muscles of Expression.*

Muscles of Phonation.

21. Makes tense the vocal cords.
22. " " and separates the vocal cords.
23. Approximates and relaxes the vocal cords.
24. Relaxes the vocal cords.
25. Approximates the vocal cords, posteriorly.
26. Depress the glottis, compress (partly) the sacculi laryngis.
27. Compress the sacculi laryngis.
28. Constricts the superior aperture of the larynx in swallowing.
29.
30. } Muscles of the external ear (all rudimentary).
31.
32. Increases the tension of the membrana tympani (probably a liga-
33. mentous structure).
34. Compresses the contents of the vestibule.
35. Elevates the posterior part of the soft palate.
36. Makes tense the soft palate by drawing it laterally on each side.
37. Approximates the uvula to the post. nasal spine.
38. Narrows the fauces, and draws the base of the tongue upward during the act of swallowing.
39. Contract and nearly meet at the uvula during the second stage of deglutition.
40. *Muscles of Deglutition.*
41. **First Period**: Muscles of the tongue (*which see*).
42. **Second Period**: Elevators of the os hyoides (*which see*), superior,
43. middle, and inferior constrictors of the pharynx, stylo-pharyngeus,
44. palato-pharyngeus.
45. **Third Period**: *Muscular fibres of the œsophagus*

MUSCLES ACTING ON THE OS HYOIDES, LARYNX, EYELIDS, EYEBALL, AND PERINEUM; ALSO, MUSCLES OF MASTICATION AND RESPIRATION.

1.
2. } **Os Hyoides** and **Larynx**: Elevation and depression.

3. *Depressors:* Sterno-hyoid, sterno-thyroid, thyro-hyoid, omo-hyoid.
4. 5. 6. 7. 8. *Elevators (also depressors of the lower jaw)*, Digastric, stylo-hyoid (no action on the inf. maxillary bone), mylo-hyoid, genio-hyoid.
9. *Muscles of Mastication.*
10. *Levators of the lower jaw:* Temporal masseter, external pterygoid,
11. internal pterygoid.
12. *Buccinator:* (Concerned in) this muscle also assists in keeping the
13. food between the molar teeth during mastication.
14. Eyelids.
15. *Opened by:* Levator palpebræ. *Closed by:* Orbicularis palpebrarum.
16. Eyeball (Wells on *The Eye*):
17. *Upward:* Sup. rectus and inf. oblique.
18. *Downward:* Inf. rectus and sup. oblique.
19. *Inward:* Internal rectus.
20. *Outward:* External rectus.
21. *Upward and inward:* Sup. rectus, int. rectus, inf. oblique.
Upward and outward: Sup. rectus, ext. rectus, inf. oblique.
Downward and inward: Inf. rectus, int. rectus, sup. oblique.
Downward and outward: Inf. rectus, ext. rectus, sup. oblique.
22. *Guides the tears into the lachrymal sac, which it compresses.*
23. *Muscles of Respiration* (Flint's *Physiology*).
24. Inspiration.
25. *Ordinary;* Diaphragm, scalenus anticus, scalenus medius, scalenus pos-
26. ticus, intercostales externi, levatores costarum.
27. *Ordinary auxiliaries:* Serratus posticus superior, sterno-cleido-mas-
28. toid.
29. 30. 31. 32. *Extraordinary auxiliaries:* Levator anguli scapulæ, trapezius (*sup. portion*), pectoralis major and pectoralis minor, serratus magnus.
33. Expiration.
34. 35. 36. *Ordinary:* Intercostales interni, infracostales, serratus posticus inferior, triangularis sterni.

37.
38.
39.
40. *Auxiliaries:* Obliquus abdominis externus and internus, transversalis, sacro-lumbalis.
41.
42.
43.

Muscles of the Perineum.

44. Supports the lower end of the vagina and rectum, supports and elevates the prostate body, opposes the action of the diaphragm.
45. Accelerates the flow of urine or semen, compresses the erectile tissue of the bulb, and dorsal vein of the penis.
46. Compresses crus and maintains erection.
47. Supports the tendinous centre.
48. Assists in discharging the contents of the urethræ.
49. Supports the coccyx.

NOTES.

I. The celebrated classification of Robin, as given by many physiologists, divides the constituents of the blood-plasma into the following divisions: 1, Organic nitrogenized principles; 2, Organic non-nitrogenized principles; 3, Inorganic principles; 4, Organic saline principles; 5, Excrementitious matters. The blood also contains carbonic acid gas, hydrogen, and oxygen.

These are the so-called proximate principles. A proximate principle may be a simple elementary substance or a compound. Water is a proximate principle, because as water it exists in the tissues and gives them certain properties. Oxygen is also a proximate, because as oxygen it gives to the tissues certain properties. Now, as the blood is the great nutritive fluid of the body, constantly carrying materials to the tissues for their regeneration and their growth, and as constantly receiving from them worn-out, effete, excrementitious matters which have no function to perform in the economy, and must be gotten rid of, carrying oxygen to the tissues and bringing carbonic acid gas to the lungs, acting at once as "purveyor and scavenger," there must come a time when the blood by its constant loss to the tissues becomes impoverished and must itself receive nourishment. This we know is furnished by the various digestive organs in the alimentary canal, and as absorption is constantly taking place from the alimentary canal, this must be replaced by nutritive material from some other source; and this source is the external world, both the organic and inorganic divisions of nature furnishing food in obedience to the demands of the organism. To the materials thus furnished by the animal and vegetable kingdoms, as well as inorganic matters, the name of proximate principles has been given. They are introduced into the body from without, are acted upon and digested by the various fluids which they encounter in the alimentary canal, and are absorbed into the blood in a condition to visit and support the tissues during their physiological activity.

II. The cause of the coagulation of the blood is not known. It is supposed to be due to changes induced by decomposition of the plasmine into metalbumen and fibrin whenever those molecular changes concerned in nutrition cease. Normally, while the blood is circulating it is constantly changing, giving material to the tissues and receiving nutriment from the alimentary canal. Whenever these changes cease, from whatever cause, coagulation takes place. When blood escapes into the surrounding tissues during life, it coagulates: it may remain liquid, however, if effused into the serous cavities, coagulating when let out. Various theories have been put forth to account for the coagulation of the blood. The one proposed by Richardson in 1856—viz. that the blood normally contains a small quantity of ammonia, which keeps the fibrin in solution—is now abandoned, because the blood is now known not to contain ammonia; the theory of Richardson being that when the blood was exposed to the air the ammonia evaporated and coagulation took place. Blood will coagulate in a vacuum, and a small quantity of ammonia added to it will not prevent the change from taking place. The theory now adopted by the most eminent teachers of physiology is that of A. Schmidt, which supposes the coming together of the fibrin-factors—fibrinogen and fibrino-plastin. The process is briefly as follows: If to the liquid portion of the blood a small quantity of acetic acid be added, just sufficient to render it neutral, and then ten times its bulk of water at 32° F., and a current of carbonic acid gas passed through it for a short time, a precipitate is formed which is called fibrino-plastin. Remove this, and to the remaining liquid add twice its volume of water at 32° F., and pass through it for a considerable length of time a current of carbonic acid gas, when a delicate film is formed; this is called fibrinogen. These two principles together in solution in the presence of a third principle, the ferment, which is furnished by the blood-plaques or by leucocytes, will come together to form fibrin, resulting in the formation of a clot. Coagula sometimes occur in the heart and vessels before death: in the vessels they are called thrombi and emboli. Those that occur in the heart before death are firmer and whiter (and nearly free from corpuscles) than those that occur after death. The arteries are generally empty after death; the venous system containing the blood. This is due to the post-mortem contraction of the walls of the arteries, coagulation taking place in from sixteen to thirty hours after life is extinct.

III. The red corpuscles are supposed to be developed from pre-existing white cells and from marrow-cells coming from the red marrow of

bones. The spleen is also thought to be a source of the red corpuscles—a theory formerly abandoned, but recently revived. The blood-plaques are thought to furnish nuclei for their development. The white cells are developed early in embryonic life from the mesoblast—supposed also to be formed by the spleen, liver, and lymphatic glands, because they occur in greater numbers in the blood coming from these organs than in that going to them. They appear early in fœtal life, before the formation of the spleen, and continue to be formed if this organ be extirpated. It has been called the graveyard of the red cells and the birthplace of the white; but in the light of recent experiments this assertion no longer stands valid. Both kinds of cells are probably formed by a true genesis from the nutritive materials existing in the plasma, and no organ or set of organs are solely concerned in their production.

Red cells appear earlier than white ones, and are of large size and contain a nucleus even as late as the fourth month of embryonic life. If it be granted that the spleen forms corpuscles, it is not absolutely necessary that this is their only source, for they will be formed, as stated above, in the absence of this organ.

IV. In vacuo the blood will give off half its volume of gases. These are, mainly, oxygen, which is in a state of chemical combination with the hæmaglobine, forming oxyhæmaglobine; and carbonic acid gas, in a state of chemical union with the salts of the liquid portion, as carbonates and bicarbonates. There are about two parts of carbonic acid gas to one part of oxygen.

V. **Preparation of Blood for Microscopical Examination.**—Sufficient blood for class demonstration can be obtained at any time from one of the fingers, the one generally selected as most convenient being the index finger of the left hand. The method is as follows: Wrap the end of a handkerchief once or twice around the extended digit, the dorsal surface up; if it be applied with sufficient pressure, it will retard the return flow of blood in the veins and cause the skin to assume a dusky-red color. Now flex the finger by bending it down, and it will be noticed that the congestion increases and the color becomes more pronounced. The next step is to rupture the cuticle, which is most effectively accomplished by a quick and rather sudden thrust with a pin or needle, using just sufficient force to fairly introduce the point. By alternately flexing and extending the end of the finger the drop of blood can be increased or diminished in size at will.

The first drop that exudes should be wiped off, as it will probably contain some scales of epithelium from the skin. The next that appears

should be used by obtaining a very small quantity on a cover-glass or glass slide; if the cover-glass be used, simply touch the drop of blood with the surface of the glass, when a sufficient quantity will adhere for all practical purposes; invert the cover-glass and place it on a glass slide; gently press upon it, and the blood will spread out as a thin layer between the two glasses. Thin layers are much more satisfactory than thick ones. It is now ready to be placed in position on the stage and examined.

(1) THE EXAMINATION.—A practical point in the examination of all microscopical specimens is to focus away from, and never toward, the object: by observing this rule it seldom happens that the observer breaks the cover-glass and frequently ruins the specimen—an accident which sometimes occurs when the eye is *first* applied to the eye-piece and the objective pushed *toward* the object. The objective should first be brought down as close as possible to the cover-glass; then the eye applied to the eye-piece, and the adjustment moved in such a way as to cause the objective to move *away* from the object.

(2) PLASMA.—The liquid portion of the blood, or *liquor sanguinis*, is, as a general thing, clear, and therefore not an object for examination.

(3) RED CELLS.—These appear in great numbers, and in the fresh specimen are moving in all directions: slight pressure with the point of a needle or small knife causes them to move with increased vigor and rapidity. They appear as circular discs when the flat surface is turned toward the eye of the observer; when they roll over and stand on the edge, they are biscuit-shaped. If one cell be selected and carefully observed after proper focusing, it will appear to have a dark or yellowish circumference and a lighter centre. If the objective be brought a little nearer the cover-glass, the centre becomes dark and the periphery light, showing that the centre and margin are not of the same thickness, hence cannot both be in focus at the same time. The red blood-cells of man and mammals have no nucleus, but are biconcave, the centre being much thinner than the circumference. Sometimes it becomes necessary to dilute the blood in order to cause the red cells to roll or to recognize the white cells. A great many indifferent fluids are used for this purpose. The serum is the best if it can be obtained. Solutions of sugar or salt may also be used if of proper density, 1027–1028. One of the best artificial fluids for use in examinations, and also one that will preserve the blood-cells for years, is the Pacinian fluid, composed as follows:

Bichloride of mercury	1 part.
Chloride of sodium (pure)	2 parts.
Glycerin (25° Beaumé)	13 "
Distilled water	113 "

This preparation is to stand for from eight to ten weeks. When used, one part of it should be mixed with three parts of distilled water and filtered. It is a good preservative mixture for all kinds of delicate tissue. Another very useful fluid, and one easily obtained, is Müller's eye-fluid, prepared as follows:

Bichromate of potash (cold sat. sol.)	1 part.
Sodium sulphate (cold sat. sol.)	5 parts.
Distilled water	10 "

Shortly after the blood is prepared for examination the red cells tend to arrange themselves in long rolls or in piles like rouleaux of coin; this is supposed to be due to the exudation of a sticky substance on their surface, which is a post-mortem formation and causes them to adhere to each other when they come together. By gently pressing on the cover-glass the cells may be made to separate, when a delicate fibril may be observed stretching between them, which contracts and draws them together again when the pressure is removed.

(4) Changes in Shape.—Subjected to certain conditions, the blood-cells lose their smooth outline and become wrinkled, spined, or corrugated. When diluted with solutions of sulphate of sodium or magnesium or concentrated solutions of salt, sugar, or gum, the blood-cells become wrinkled and shrivelled, having an irregular or zigzag border. As the shrinking proceeds they become smaller, and grow small projecting processes or spines all over their surface; they then have what is called the *horse-chestnut shape*. Some observers suppose this condition to be due to the loss of carbonic acid, as the addition of this gas restores their smooth outline, and its abstraction produces the irregular condition again. Distilled water causes them to swell up and finally disappear. This is an excellent method to render clear the nucleus of the red cells of amphibians, fishes, reptiles, and birds. When heated on the stage to 52° C., a number of globules are rapidly formed on the surface of the cell, which often become attached to each other by delicate fibrillæ, producing a beaded appearance: when they become separated, they show a lively molecular movement (M. Schultze). Rapidly dried,

they show as a light ring with regular border, bounded by a dark one. Red blood-cells will become irregular in outline if the specimen of blood be allowed to stand for a short time without the addition of any reagent, evaporation alone being sufficient to produce the result.

(5) Restoration of Shape from Old Blood-stains.—The shape of the red cells can be restored from specimens obtained from old blood-clots or blood-stains after many years. If a piece of fabric of any kind bears the stain, take a very small piece—a single thread will suffice—put it in a watch-crystal or other small vessel, and add a few drops of an 0.8 per cent. solution of sodium chloride, and allow it to stand until softening of the thread takes place: examination of the fluid will now disclose the red cells restored to nearly their original size and shape. In this way it is possible to tell the nature of doubtful stains, and whether the blood be of mammalian origin, the blood of mammals, including man, being characterized by the circular, non-nucleated, biconcave red blood-cells, whereas the red blood-cells of fishes, amphibians, reptiles, and birds are oval and nucleated. The red blood-cells of the camel tribe are also oval: this forms the exception in the class Mammalia.

Such questions become of importance in connection with medico-legal investigations. It is possible for the microscopist to say that the stain is of mammalian origin or not, but he can go no further: he cannot affirm that it is from this mammal or from that, though some microscopists claim to be able to tell with certainty the different mammalian blood-cells. This accuracy of recognition must come from frequent and prolonged examinations of specimens of blood from different mammals.

(6) White Blood-cells.—Owing to the relatively small number of white blood-cells in normal blood, some little difficulty is ordinarily experienced in their examination. It is possible with large magnification to see their movement without the addition of any reagent. Upon the addition of heat to 38° or 40° C. the amœboid movements increase and the corpuscle becomes very lively, throwing out processes of its protoplasm and frequently changing its form as well as position in the field. These blood-cells are larger than the red cells, are spherical or globular in shape, white in color, and granular and nucleated in structure; frequently one cell contains several nuclei; especially is this the case in large cells. They have the power to take in granules from the surrounding liquid, and are said by some observers to be active in destroying certain micro-organisms which, when in the blood-current, cause disease. The nucleus can be brought into prominence by the

addition of dilute acetic acid, which clears up the surrounding protoplasm and brings the nucleus into view; generally three nuclei are found in each cell. Nuclei may be seen in the intranuclear network of fibrillæ.

(7) The Blood-plaques or Blood-plates occur as angular granules. In fresh blood they are pale circular or oval discs (Bizzozero).

(8) The structure of a clot and the appearance of fibrin may be observed by allowing a small quantity of blood to coagulate on a glass slide, or by making sections from a contracted clot. The fibrin exists as a delicate network of very fine fibrils, in the meshes of which are entangled red and white blood-cells.

(9) Coloring-matter of the Red Blood-cells.—This is called hæmoglobine, hæmoglobuline, hæmocrystalline, and it can be obtained in the crystalline form, the crystals differing in shape in the blood of different animals. Crystals of the blood-pigment (hæmin) can be procured by placing a thread impregnated with the fluid on a slide, adding a few drops of glacial acetic acid, a small quantity of chloride of sodium (table salt), and gently heating until ebullition begins; as cooling takes place the crystals can be seen forming along the course of the thread, very much as rock candy crystallizes around its central thread. The color of the crystals is a dark brown of various shades. These are the so-called "*hæmin crystals of Teichmann*": they can be extracted from blood-stains, however old, and hence are of great importance in determining whether suspected stains are of bloody origin.

GLOSSARY.

Ab-do'men. [L. *abdere*, to conceal.] The belly cavity, bounded below by the pelvis, and limited above by the diaphragm, which separates it from the thoracic cavity.

Ab-duc'tor. [F. *abducteur*; L. *ab*, from, and *ducere*, to lead.] A name applied to those muscles which move parts of the body away from the median line.

Ab-la'tion. [L. *ab*, from, and *latum*, to take.] Removal.

Ab-nor'mal. [L. *ab*, from, and *norma*, rule.] Not normal, irregular.

A-bom-a'sus. [F. *caillette.*] The fourth or true stomach of ruminants.

Ab'scess. [L. *abs*, and *cedere*, to depart.] A collection of matter or pus in a cavity as a result of the destruction of normal tissue.

Ab-sorp'tion. [L. *absorbere*, *ab* and *sorbere*, to drink or suck up.] A peculiar function of vessels by which they draw into their lumen the various fluids of the body.

Ac'ci-dent. [L. *ac*, and *cedere*, to happen.] An unavoidable or unforescen event.

A-ce-tab'u-lum. [L. *acetum*, vinegar; F. *acetabule.*] The cavity in the ossa innominata or pelvic bones for the reception of the head of the femur, so called because it has been likened to the small vinegar vessel of Roman antiquity.

Ad-duc'tor. A name applied to muscles which draw parts of the body toward the median line.

Ad'i-pose [L. *adipis*, fat; F. *adipeux.*] A name applied to the fatty tissue of the body.

A-dul-ter-a'tion. [L. *adulteratio*, to corrupt.] The act of lowering the standard of purity by the addition of inferior materials.

Af'fe-rent. [L. *affero*, *ad* and *fero*, to bring or carry.] A name applied to vessels and nerves *leading to* organs and nerve-centres.

Al-bi'no. [L. *albus*, white.] A name applied to members of the human family with white skin and hair and pink eyes; the pigment is absent.

Al-bu'men. [L. *albus*, white; F. *albumine.*] The most important organic nitrogenous constituent of animal and vegetable life. The important part of the white of egg.

Al'co-hol. [A word of Arabic origin.] A colorless inflammable liquid, of a pungent smell, capable of acting as an irritant and powerful stimulant to animal tissues. Obtained by the distillation of vegetable infusions and juices, which have been fermented by the action of zymotic micro-organisms.

Al'co-hol-ism. Diseased conditions of the body, with liver and kidney affections, dropsies, etc., caused by the excessive use of alcohol.

Al'i-ment. [L. *alere*, to feed or to nourish.] Any food having power to nourish the system.

Al'ka-li. [Arab. *al*, the, and *kali*, the name of a soda-containing plant,—salsola soda.] Substances forming salts with acids, and having the power to give the blue color to litmus which has been reddened by acids.

Al'ka-loid. [Alkali, and Gr. ειδος, form.]

An organic alkali, resembling the mineral only in basic properties. A name given to the active nitrogenous principle of many drugs.

Am'bu-lance. [L. *ambulare*, to walk.] A wheeled vehicle for carrying the wounded.

Am-œ'boid. [Gr. αμειβω, to change, and ειδος, like or resemblance.] A name given to the movements observed in white blood-cells, pus-cells, etc.

An-œ'mi-a. [Gr. from *an*, άιμα, blood.] Without sufficient blood. Lessened relative number of red blood-cells.

An-æs-the'si-a. [F. *anesthésie;* Gr. *an*, against, and *aisthanomai*, to feel.] Loss of sensibility.

A'nal. [*Ana'lis*, ani, a circle.] Relating to the anus, or lower opening of the rectum.

A-nat'o-my. [Gr. from *ana*, through, and τημνειν, to cut.] The study of all organized bodies. Literally, dissection.

An-thra-co'sis. [*Anthrax* and *osis.*] A name applied to coal-miners' lung. A disease of the lungs due to the inhalation of particles of carbon.

An'ti-dote. [From *anti*, against, and Gr. διδωμι, to give.] A remedy given to counteract the effect or action of a poison.

An'trum. [Gr. αντρον, a cavern ; F. *antre.*] A name applied to cavities in bone having a small opening leading to them.

A-or'ta. [L. *aorta*; Gr. αορτεομαι, to be suspended.] The largest artery of the body, coming from the left ventricle, from which it seems to be suspended. So named by Aristotle.

Ap-o-neu-ro'sis. [Gr. *apa* and νευρον, a nerve.] A flattened interlacement of white connective-tissue fibres, developed in the course of muscles, and also serving to attach them to bone.

A-poph'y-sis. [Gr. from *apo* and φυο, to rise.] An excrescence, a process of bone growing upon bone, from which it has never been separated.

Ap'o-plex-y. [Gr. from αποπληττειν, to strike with violence.] A sudden effusion of blood into an organ or tissue, generally used to indicate an escape of blood into the substance of the brain.

Ap'pe-tite. [L. *ap*, and *petere*, to seek.] The first promptings of hunger.

Aq'ue-duct. [L. *aqua*, water, and *ducere*, *ductum*, to lead.] Used by anatomists to designate certain canals which communicate with important parts of the body.

A-rach'noid. [*Arachne*, and ειδος, form, resemblance.] A spider-web-like membrane surrounding the brain, between the dura mater and pia mater.

Ar'te-ry. [Gr. αηρ, air, and τηρειν, to contain.] Aërial canal, a name erroneously applied by Praxagoras to the aorta and its ramifications. A vessel carrying pure blood.

As-phyx'i-a. [Gr. from *a*, without, and *sphyxia*, pulse.] Apparent death from suffocation, caused by the non-aëration of the venous blood of the lungs.

Au-di'tion. [L. *audire*, *auditum*, to hear.] The act of hearing.

Au'ri-cle. [L. dim. of *auris*, the ear.] Part of the external ear. The upper cavities of the heart, which have a dog-ear-like appendage.

Ax-il'la. [L. *axilla*, the armpit, dim. of *ala.*] The hollow below the union of the shoulder and arm.

Az'y-gos. [Gr. from *a*, and ζυγος, a yoke.] Having no mate.

Ban'dage. [F. *bande;* Sax. *bindan*, to bind.] To wrap up; also the act of applying the bandage. A piece of calico or muslin of varying length and width used by surgeons to protect and support wounds.

Bas'il-ar. [F. *basilaire.*] Pertaining to the base.

Bel'ly. [From Ir. *bolg*, a bag or pouch.] The abdomen.

Ber'tin. A distinguished French anatomist.

Bi'ceps. [L. *bis*, twice, and *caput*, head.] Having two heads.

Bi-cus'pid. [L. *bis*, twice, and *cuspis*, *cus-*

pidis, a spear.] Applied to a tooth with two cusps or points.

Bi'fur-cate. [L. *bis*, twice, and *furca*, a fork.] To divide into two.

Bi-ol'o-gy. [Gr. βιος, life, and λογος, a discourse.] The science or doctrine of life.

Bi'o-plasm. [Gr. βιος, life, and πλασσω, to form.] A term used by Dr. Lionel S. Beale to denote the living matter of all plant and animal life.

Blas-te'ma. [Gr. from βλαστανο, to bud.] The formative matrix of any tissue.

Blood. [Sax. *blod*, from, *bledan*, to bleed.] The great nutritive fluid of the body.

Bra'chi-al. [L. *brachium*, arm.] Pertaining to the arm.

Bron'chi-a. [L. *bronchus*, and *trachea*.] One of the divisions of the trachea or windpipe.

Bron-chi'tis. [L. *bronchus*, and *itis*.] Inflammation of the lining membrane of the air-tubes.

Bur'sa. [Gr. βυρσα, a sac or leathern bottle.] Oil-sacs about joints over which tendons play.

But'ter. [Gr. βους, ox, and τυρος, anything coagulated; F. *beurre*.] A substance made from the cream or fatty particles that form on the surface of the milk of the female mammalia, especially the cow.

Ca-da'ver. [L. *cado*, to fall, or *cavo data vermibus*, flesh given to the worms.] A dead body. A carcass. A subject for dissection.

Cæ'cum. [L. *cæcus*, blind.] That part of the intestine between the ilcum and the beginning of the large gut or colon.

Caf'fein. The active alkaloid of Coffea arabica.

Ca-nal-ic'u-lus. [L. dim. of *canalis*, a channel.]. A little canal.

Ca'nine. [L. *canis*, a dog.] A name applied to teeth resembling those of a dog.

Cap'il-lary. [L. *capillus*, a hair.] A name given to the small hair-like vessels connecting the arteries and veins.

Ca'put. [L. *caput*, the head, gen. *capitis*.] The head. A term of general application to enlarged parts of tissues in any portion of the body.

Car-bon'ic Acid. [L. *acidum carbonicum*.] A gas produced by the combustion of carbon in oxygen. It will not support respiration, though it is not poisonous in the presence of sufficient oxygen. As it collects in mines, wells, and caverns it forms the dreaded *choke-damp*. Lime thrown into such places absorbs the choke-damp.

Car'di-ac. [Gr. καρδια, the heart.] Relating to the heart.

Car'pus. The wrist.

Car'ti-lage. Gristle. A substance found in animal bodies, of a consistence between bone and ligament, found on the articular surfaces of all bones.

Ca'sein. [L. *caseus*, cheese.] The nitrogenized constituent of milk.

Ca-tarrh'. [Gr. from *cata*, and ῥεω, to flow.] An inflammation of a mucous membrane, with a discharge of fluid.

Cau'dal. [L. *cauda*, a tail.] Relating to a tail.

Cav'ern-ous. [L. *cavus*, hollow.] Filled with small spaces, as a sponge.

Cell. The smallest unit of animal and vegetable life.

Cell'u-lose. A vegetable substance resembling starch, forming the principal part of cell-walls of plant life.

Ce-phal'ic. Relating to the head.

Cer-e-bel'lum. [L. dim. of *cerebrum*.] The little brain.

Cer-e-bra'tion. [L. *cerebratio*.] The function of the brain during a mental act.

Cer'e-brum. [Gr. καρα, the head.] The brain. A name sometimes given to the front brain.

Cer'vi-cal. [L. *cervix*, gen. *cervicis*, the neck.] Anything relating to the neck.

Cheese. [Sax. *cere*.] An article of food containing the fat and casein of milk.

Chest. The thorax.

Chil'blain. [L. *chill*, cold, and *blain*, a pustule.] An inflammation produced by exposure to cold, affecting the feet and hands.

Chi'asm, [Gr. χιαζω, to mark the letter X.]

The cross formed by the crossing of the optic tracts.

Chlo'ral. [From *chlorine* and *alcohol.*] Formed by the action of chlorine on anhydrous alcohol. In doses of ten to twenty grains it is an anodyne and hypnotic.

Chol'e-ra. [Gr. from *chole*, and ῥεω, to flow.] A disease characterized by vomiting and purging, anxiety, gripings, and spasms of the muscles of the arms and legs.

Cho-les'ter-in. [Gr. χολη, bile, and στεαρ, suet.] An excrementitous substance found in the bile. The formula is ($C_{26}H_{44}O$). Soluble in alcohol, and crystallizable. It is also found normally in the liver, nervous tissue, blood, and changed into stercorine it exists in the fœces.

Cho'roid. [Gr. *chorion*, the skin, and ειδος, resemblance.] Any tissue resembling the skin. The second membrane or tunic of the eyeball.

Chyle. [Gr. χυλος, juice, from χυω, to pour.] A term used first by Galen for nutritive matters absorbed by the intestinal mucous membrane.

Chyme. (Derivation same as chyle.) The pultaceous mass of food in the stomach and upper part of the duodenum.

Cil'i-a-ted. [L. *cilium*, hair.] Provided with hair or hair-like processes.

Cir-cu-la'tion. [L. *circum*, around, and *ferre latum*, to carry.] The passage of the blood through the different divisions of the vascular system.

Clav'i-cle. [L. *clavis*, a key.] The collar bone.

Cli'noid. [Gr. *cline*, a bed, and ειδος, form.] Like a bed-post.

Clot. [D. *kloot*, a ball, or *kluit*, a clod.] The name applied to a mass of curdled or coagulated blood.

Co-ag-u-la'tion. [L. *cogo coactum*, or *co* and *agere*, to bring together.] The change of a liquid into a semi-solid mass.

Coc'cyx. [Gr. κοκκυγος, a cuckoo.] A name applied to the small bones attached to the lower end or apex of the sacrum, from their fancied resemblance in shape to a cuckoo's bill. The crupper-bone.

Coch'le-a. [L. a snail.] A spiral cavity of the internal ear.

Co'ma. [Gr. κομεω, to adorn.] A deep sleep.

Com'mis-sure. [L. *com*, and *mitto*, to join together.] The point where converging parts unite.

Con-junc-ti'va. [L. *con*, and *jungere junctum*, to join together.] The membrane lining the eyelids and covering part of the eyeball.

Con-vul'sion. [L. *con*, and *vellere, vulsum*, to tear or to pull together.] Involuntary and violent muscular contractions.

Cor'a-coid. [Gr. κορακος, a crow, and ειδος, resemblance.] A name applied by Galen to a process of the scapula, from a fancied resemblance to a crow's beak.

Cor'ne-a. [L. *cornu*, a horn.] A convex transparent tunic covering the anterior part of the globe of the eye.

Cra'ni-um. [Gr. κρανος, a helmet.] The bony case which contains the brain and its membranes.

Cras-sa-men'tum. [L. *crassus*, thick.] A clot of blood.

Cru'ra cer'e-bri. [L. pl. of *crus*, a leg, and καρα, the head.] Peduncles or legs of the brain. Rounded masses of longitudinal nerve-fibres, containing each a layer of gray matter, which run from various parts of the cerebrum to the superior portion of the pons Varolii.

De-cus'sate. [L. *decussare, decussatum*, to cross X.] To cross in the form of the letter X.

Def-e-ca'tion. [L. *de*, and *faex*, gen. *faccis*, excrement.] The act by which the effete residue of the alimentary mass is discharged from the body.

De-gen-er-a'tion. [L. *de*, and *genus, generis*, family.] Unlike the race or family. To grow worse.

De-lir'i-um. [Gr. *de*, and ληρημα, a silly saying.] A symptom characterized by perverted reason and unnatural actions. Wandering of the mind.

Del'toid. [Δ, *delta*, and ειδος, resemblance.]

The large muscle covering the shoulder-joint.

Den'tal. [L. *dens, dentis*, tooth.] Relating to the teeth.

Der'mis. [L. *derma*, the skin.] The chief layer of the skin.

Dex'trin. [L. *dexter*, right-handed.] A substance derived from starch by treatment with sulphuric acid (H_2SO_4); so called because it turns the rays of polarized light strongly to the right.

Di-a-be'tes. [Gr. *dia*, and $\beta\alpha\iota\nu\omega$, to pass.] Probably an essential fever. A disease in which the secretion of the kidneys is much increased and altered. In D. Mellitus there is sugar in the urine, excessive thirst, and progressive loss of body-weight.

Di'a-phragm. [From *dia*, and $\phi\rho\alpha\sigma\sigma\omega$, I close.] The muscular partition between the thorax and abdomen. The most important muscle of respiration.

Di'as-tase. [Gr. to place.] A vegetable ferment capable of converting starch into sugar.

Di'as-tole. [Gr. to dilate or to open.] Dilatation of the heart.

Di-ges'tion. [L. *digestio*, from *digere*, *digestum*, to digest.] The preparation of food matters for absorption.

Dig'i-tal. [L. *digitus*, finger.] Relating to the fingers.

Di-ver-tic'ulum. [L. *di*, and *vertere*, to turn aside.] A small tube or sac developed in the course of a larger one.

Duct. [L. *ducere*, *ductum*, to lead.] A small tube or canal.

Du-o-de'num. [L. *duodeni*, twelve.] The first part of the small intestine, about as long as twelve fingers are wide.

Du'ra ma'ter. [L. *dura*, hard, and *mater*, mother.] The heaviest and strongest tunic of the brain and cord,

Dys-pep'si-a. [*dys*, and $\pi\epsilon\pi\tau\omega$, to concoct.] A perverted condition of the stomach by which it is unable properly to act upon food.

Dys-pnœ'a. [Gr. *dys*, and $\pi\nu\epsilon\omega$, to breathe.] Difficulty of breathing. Painful breathing.

Ear. The organ of hearing.

Ed'i-ble. [L. *edere*, to eat, and *habilis*, able.] Fit for food. Esculent.

Ef-fete'. [L. *effetus*, from *ex*, out, and *fœtus*, producing.] Barren. Worn out. Dead.

El'e-ment. [*Oleo*, to grow.] The simplest constituent factor forming the tissues of organized bodies.

E-ma'ci-ate. [L. *emaciare*, *emaciatum*, *e* and *maceo*, to be lean.] To waste away; to lose flesh.

E-mul'sion. [L. *emulgere*, *e*, and *mulgere*, *mulsum*, to draw out.] A name generally applied to oils and fats which are finely divided and held in suspension in a liquid medium.

En-am'el. [F. *en*, and *émail*.] The hardest substance in the body. The white substance which covers the crowns of the teeth.

Ep-i-der'mis. [Gr. *epi*, upon, and *derma*, the skin.] The part of the covering of the body which raises as a blister.

Ep-i-glot'tis. [Gr. *epi*, upon, and *glotta*, the tongue.] A cartilaginous structure protecting the entrance to the windpipe. The cover of the glottis.

Ep-i-stax'is. [*Epi*, and $\sigma\tau\alpha\zeta\omega$, to flow drop by drop.] Nose-bleed.

Er-y-throx'y-lene. [Gr. *erythro*, red, and $\xi\upsilon\lambda o\nu$, wood.] The name applied to cocaine by Gaedeke in 1855.

Eu-sta'chi-an Tube. A canal leading from the throat to the middle ear. Named after the celebrated anatomist, Eustachius.

Ex-cre'tion. [L. *excernere*, *excretum*, *ex*, and *cernere*, to separate.] An animal fluid that has no function to perform. Waste or worn-out matter.

Ex-pi-ra'tion. [L. *ex*, and *spirare*, to breathe out.] The act of throwing air out of the lungs.

Ex-ten'sor. [L. *ex*, and *tendere*, to stretch or draw out.] A muscle that opposes flexion.

Face. [L. *facere*, to form.] The front part of the head, composed of fourteen bones.

Fal'ci-form. [L. *falx, falcis*, a scythe, and *forma*, shape.] Scythe-shaped.

Far-i'na. [*Far*, corn or any kind of grain.] Flour or meal from the seeds of cucurbitaceous and gramineous plants. Farina tritici, wheat flour.

Fas'ci-a. [L. *fas*, that which is binding.] Bands of fibrous connective tissue surrounding muscles and various parts of the body.

Fer-men-ta'tion. [L. *ferveo*, to boil.] A change taking place in sugary solutions, with the production of alcohol and carbonic acid gas, due to the growth and multiplication of minute plant-life. "Life without air."—P.

Fe'ver. [L. *feritas*, wildness, *februo*, to purify, or *fervor*, heat.] A perverted condition of the system with increased body-heat.

Fi'bre. [L. *fibra*, a thread.] A thread of organic matter found in plant and animal life.

Fon'ta-nelle. [L. *fons, fontis*, dim. a fountain.] Open spaces between the bones of a young child's head.

Frac'ture. [L. *fractura, frangere, fractum*, to break.] To break. Generally applied to a broken bone.

Func'tion. [L. *fungor, functus*, to act.] The normal action of an organ or part.

Fu-mi-ga'tion. [L. *fumus*, smoke, *fumigare, fumigatum*, to make smoke.] The act of filling a room or space with vapor, gas, or smoke for purposes of purification.

Gall'-blad-der. A membranous reservoir for the bile, situated in the cystic fossa on the under surface of the right lobe of the liver,

Gan'gli-on. [Gr. γαγγλιον, a knot.] An enlargement in the course of a nerve containing some gray matter.

Gas'tric. [From *gaster*, belly.] Relating to the stomach.

Gel'a-tin. [L. from *gelare*, to congeal, to freeze.] An animal substance soluble in hot water, and setting into a jelly on cooling.

Gen'e-rate. [L. *genere, gignere*, or *generare, generatum*, to engender, to beget.] The functions leading to reproduction. To make or produce.

Gland. [L. *glans*, dim. *glandula*, an acorn.] An organ concerned in separating something from the blood, as the liver, kidney, spleen, testicle, etc.

Glu'ten. [*Glue*, paste, gen., *glutinis.*] An elastic nitrogenized vegetable principle.

Gly'co-gen. [Gr. *glyco*, sugar, and *gennao*, to engender.] One of the products of the liver-cells which is readily changed into sugar and used normally in the processes of nutrition.

Gran'ule. [L. dim. of *granum*, a grain.] Small grain-like particles.

Gus-ta'tion. [L. *gustare, gustatum*, to taste.] The sense of taste.

Gy'rus. [Gr. γυρος, a circle.] A convolution of the brain.

Hæ-ma-tem-e'sis. [*Hæmato*, and εμεω, to vomit.] Vomiting of blood, which is generally grumous or dark.

Hæ-mo-glo'bin. [*Hæma*, and *globus*, a ball or globe.] The name of the coloring matter in the red-blood-cells.

Hæ-mo-pty'sis. [*Hæmo*, and πτυω, to spit.] Hemorrhage from the lungs.

Hem'or-rhage. [Gr. *hæma*, and *regnumi*, to break forth.] The escape of blood from its normal channels.

Hal-lu-ci-na'tion. [L. *hallucinari, hallucinatum*, to be deceived; to blunder; to dream.] Imaginary perception of objects which are not within the range of the senses, or which do not exist, caused by derangement of the nervous system. Not necessarily indicative of insanity.

Hy'giene. [Gr. ὑγιεια, health.] The science of the laws of health.

Hy-per'tro-phy. [*Hyper*, excessive, τροφη, nourishment.] Of great size. Enlargement.

Hys-te'ri-a. [Gr. ὑστερα, the uterus.] A peculiar affection of females, characterized by alternate fits of crying and laughing, with the sensation as if a ball

were rising from the belly to the neck, producing a sensation of strangulation.

Id-i-o-path'ic. A disease not depending on any other. First affection.

Id'i-ot. [Gr. ἰδιωτης, an ignorant person.] One low in intellect. One incapable of taking care of himself.

Il'e-um. [Gr. ειλειν, to twist, to turn.] The name of the lower end of the small intestine.

Im'pulse. [*Im*, and *pellere*, *pulsum*, to drive.] A motion of the heart. An influence which travels over nerve-fibres.

In-ci'sor. [L. *incidere*, *incisum*, to cut.] A cutter. A name applied to flat-cutting front teeth.

In'du-ra-ted. [L. *in*, and *durus*, hard.] Hard. A condition occasionally following inflammation of tissues.

In-fec'tious. [L. *inficere*, *infectum*, from *in*, and *facere*, to make, to taint.] Having power to infect.

In-flam-ma'tion. [L. *inflammare*, from *in*, and *flammare*, to flame.] An abnormal function of tissues, characterized by heat, pain, redness, and swelling, with an increased determination of blood to the affected part.

In-spi-ra'tion. [L. *in*, and *spirare*, *spiratum*, to breathe.] The act of taking air into the lungs.

In-suf-fla'tion. [L. *in*, *suf*, and *flare*, to blow.] The act of blowing air into anything.

In-tes'tine. [L. *intus*, within.] The bowel, that part of the alimentary canal below the stomach.

In-tox'i-cate. [L. *intoxicare*, *intoxicatum*, to drug or poison; *toxicum*, a poison.] To poison. To make drunk, as with alcoholic liquors.

In'va-lid. [L. *in*, and *validus*, strong.] A sick person.

In-vol'un-tary. [L. *involuntarius*, *in*, *an*, *voluntas*, will.] Not having the power of choice. Independent of the will, not necessarily against it; as the acts of respiration, the beating of the heart, etc.

I'ris. [L. *iris*, *iridis*, the rainbow.] The colored curtain behind the cornea in which is located the pupil.

Isch'i-um. [Gr. to support.] That part of the innominate bone that receives the weight when we are seated.

Je-ju'num. [*Jejunus*, empty.] The name given to the middle part of the small intestine, because it is nearly always found empty after death.

Joint. [L. *jungere*, *junctum*, to join.] An articulation formed by two or more bones coming together and admitting of motion between them.

Jux-ta-po-si'tion. [L. *juxta*, near to, and *ponere*, *positum*, to place.] Placed upon or next to, not between.

La'bi-al. [L. *labium*, a lip.] Relating to the lips. Lip-like.

Lach'ry-mal. [*Lachryma*, tear.] Relating to the tears. The name of the tear-secreting glands.

Lac'te-als. [L. *lac*, milk.] The name of those lymphatics which carry a milky fluid from the intestines to the receptaculla chyli. They carry ordinary lymph during the intervals of digestion.

Lam'i-na. [A plate.] A thin flat plate of bone, or any tissue. Dim. *lamella*.

La-cu'næ. [Dim. of *lacus*, a lake.] The spaces in the plates of osseous tissue.

Lar'ynx, lar-inks. The cartilageous box containing the organs of voice, situated at the commencement of the windpipe.

La'tent. [L. *latere*, to lie hid.] Concealed. Not active.

Le-va'tor. [L. *levare*, to raise.] A name applied to muscles which raise or elevate parts.

Lig'a-ment. [L. *ligare*, *ligatum*, to bind.] Bands of strong connective tissue serving to unite bones.

Lig'a-ture. The name of the thread or string with which a blood-vessel is tied to arrest hemorrhage.

Lob'ule. [Dim. of *lobus*.] A small lobe.

Lymph. [*Lympha*, water.] The water-like fluid contained in the lymphatics.

Mac-e-ra'tion. [L. *macerare, maceratum*, to soften with water.] To steep in water. To soak.

Mac'u-la. A spot.

Mal-a'ri-a. [L. *malus*, bad, and *aria, aer*, air.] Bad air. Miasma. Air containing the emanations of marshy localities, and capable of producing disease, fever, etc.

Malt. [Gr. to soften.] Germinated barley used in the manufacture of beer. Also used in medicine as an antiscrofulous remedy.

Mam'ma. [L. *mamma*, breast.] One of the first cries of the infant. An organ peculiar to the mammalian animals for the secretion of milk. The female breast.

Ma'ni-a. [Gr. μαινομαι, to be furious.] Furor. Perverted intellect, with false judgment and hallucinations which impel to acts of violence. A kind of insanity.

Mas'ti-cate. [L. *masticare, masticatum*, to chew.] To chew. To comminute the food between the teeth.

Me-dul'la ob-lon-ga'ta. [*Medius*, middle.] The oblong nervous mass at the upper end of the spinal cord which rests upon the basilar process of the occipital bone.

Mi'cro-scope. [Gr. *micro*, small, and σκοπη, a view.] An instrument with optical attachments for magnification, used in the study and examination of minute objects.

Mid'riff. [Sax. middle and the bowels.] The diaphragm.

Mo'lar. [L. *molaris*, a grindstone, or *mola*, a mill.] A name applied to the back teeth or grinders.

Mor'phi-a. [*Morpheus*, the god of sleep.] An active alkaloid of opium.

My-o'pi-a. [Gr. to close the eye.] Near-sightedness.

Nar-co'sis. [Gr. νάρκη, numbness.] Loss of consciousness produced by a narcotic.

Nar-cot'ic. [Gr. *narke*, stupor.] A medicine which promotes sleep, relieves pain, and in poisonous doses causes stupor, coma, and death.

Na'sal. [L. *nasus*, the nose.] Relating to the nose.

Na'vel. [Ger. *nabel.*] The depression in the front of the belly. The umbilicus.

Nerve. [Gr. *neuron*, a string.] A thread of animal matter communicating with nerve-centres along which nervous influences pass.

Neur-al'gi-a. [Gr. *neuron*, a nerve, and αλγος, pain.] A disease characterized by pain in the course of the nerves.

Neur-og'li-a. [Gr. *neuron*, a nerve, and γλία, glue.] The supporting tissue of the brain substance.

Ni'dus. [A nest.] Any delicate reticulated tissue for protection and support.

Nu-cle-o'lus. [L. dim. of *nucleus*, a kernel.] The active part or kernel of a typical cell.

Nu-tri'tion. [L. *nutrere, nutritum*, to nourish.] The phenomena by which the tissues of the body maintain their integrity by appropriating the various products of digestion, and discharging their worn-out substances.

Oc'ci-put. [L. *oc*, and *caput*, the head.] The posterior part of the cranium formed by the occipital bone.

Oc'u-lar. [*Oculis*, an eye.] Pertaining to the eye.

O-don'toid. [From *odonto*, and ειδος, resemblance.] Tooth-like. The name of a process of the second cervical vertebra or axis.

Œ-soph'a-gus. [Gr. οισω, to carry, and φαγω, to eat.] The gullet. The tube leading from the pharynx to the stomach.

O-le-cra'non. [Gr. ωλευν, the elbow, and κρανον, the head.] The upper extremity of the ulna which forms the prominence of the elbow.

Ol-fac'to-ry. [L. *olfacere, olfactum*, from *olere*, to smell, and *facere*, to make.] Relating to the sense of smell, or the nerves of smell, which are the first pair of cranial nerves.

O-paque'. [L. *opacus*, obscure.] Not transparent. A name applied to bodies which

will not permit the rays of light to pass through them.

Oph-thal'mic. [Gr. *ophthalmos.*] Relating to the eyes.

O'pi-um. [Gr. οπος, juice.] The stupefying narcotic juice of the plant *Papaver somniferum.*

Or-bic'u-lar. [From *orbis*, a circle.] A name applied to sphincter or circular muscles, as orbicularis oris; orbicularis palpebrarum.

Os-mose', or **os-mo'sis.** [Gr. ωσμος, impulse.] The passage of fluids through moist membranes, either endosmotic or exosmotic currents.

Os-te-o-gen'et-ic, os-te-o-gen'ic. [*Osteon*, bone, and γενναω, to beget.] Bone-producing. The name of the bone-forming layer of the periosteum.

Ox'y-gen. [Gr. οξυς, acid, and γενναω, to engender.] A name applied to a gas which was supposed by the ancients to be exclusively concerned in the production of acids. A normal constituent of the atmosphere, in which condition it is indispensable to respiration. Found also in water, acids, the oxides, and in the tissues of plants and animals. Combustion goes on with great energy in its presence.

Pab'u-lum. [L. *pascere*, *pavi*, to feed.] Food.

Pain. [L. *paena*, punishment; Sax. *pinan*, to torture.] Twinges. Pang. A disagreeable sensation of varying intensity.

Pal'pe-bral. [L. *palpitare*, to palpitate.] Relating to the eyelids.

Pan'cre-as. [Gr. πᾶν, all, and κρεας, meat or flesh.] A gland in the abdomen which furnishes an important digestive fluid to the duodenum.

Pa-pil'la. A nipple. A small eminence.

Par-a-glob'u-lin. One of the factors of fibrin.

Par-al'y-sis. [*Para*, beside, and λυω, to relax.] Loss of motion or sensation, or both.

Par'a-site. [*Para*, beside, and σιτος, corn, food. To eat beside of.] Animals or plants which live upon and at the expense of other animals and plants.

Pa-ri'e-tal. [L. *paries*, a wall.] Relating to the walls of a cavity. The flat bones at the sides of the head.

Pa-rot'id. [*Para*, near, and ους the ear.] One of the saliva-forming glands, situated near the ear.

Pa-tel'la. [L. dim. of *patera*, a bowl, or *patina*, a pan.] The knee-cap or knee-pan.

Pec'to-ral. [L. *pectus*, the breast.] Pertaining to the breast. The breast muscles.

Pe-dun'cle. [L. dim. of *pes*, *pedis*, a foot.] A small prolongation or appendage.

Pel'vis. [L. *pelvis*, a basin.] The cavity below the abdomen formed by the sacrum, coccyx, and innominate bones.

Pep'sin. [Gr. πεψις, digestion.] The active organic ferment of the gastric juice.

Per-i-chon'dri-um. [*Peri*, around, and χονδρος, cartilage.] A vascular fibrous membrane covering non-articular cartilage.

Per-i-os'te-um. [Gr. *peri*, around, and *osteon*, a bone.] The membrane surrounding bone.

Per-spi-ra'tion. [L. *per*, through, and *spirare*, *spiratum*, to breathe.] Exhalation which is constantly taking place from the surface of the skin. When it is sensible it is called sweat.

Pe'trous. [Gr. πετρος, a rock.] Hard, stony. That part of the temporal bone containing the internal ear.

Phal'anx. [Gr. a row of soldiers.] The bones of the fingers and toes.

Phar'ynx. [Gr. from φαρω, to divide or cut.] The funnel-shaped cavity at the back of the mouth communicating with the œsophagus below.

Pho-na'tion. [Gr. *phone*, the voice.] The physiology of the voice.

Phys-i-ol'o-gy. [Gr. φυαις, nature, and λογος, a description or discourse.] The science which deals with the functions of plant and animal life.

Pi'a ma'ter. [Delicate mother.] The deli-

cate vascular membrane immediately surrounding the brain and cord.

Pig'ment. [L. *pingere*, *pinctum*, to paint.] Coloring matter.

Pla-tys'ma. [Πλατυς, broad.] A broad muscle at the side of the neck, rudimentary in man.

Pleu'ra. [Gr. the side or a rib.] A double-walled fibro-serous sac surrounding the lungs and lining membrane.

Plex'us. [*Plecto*, *plexum*, to interlace.] A network of nerves or blood-vessels.

Pons Va-ro'li-i. [L. *pont*, *pontis*, a bridge.] The bridge of Varolius. A part of the brain formed by the crura cerebri and crura cerebelli.

Pro'cess. [L. *procedere*, *processum*, to go forward.] A projecting part.

Pro'to-plasm. [*Proto*, first, πλασσω, to form.] A term used to denote the living matter of all plants and all animals, or the substance that first manifests the phenomena of life.

Pul'mo-na-ry. [L. *pulmo*, *pulmonis*, a lung.] Relating to the lungs. Lung-like.

Pul-sa'tion. [L. *pulsare*, *pulsatum*, to beat.] A name applied to the action of the heart and arteries.

Pu'pil. [L. from *pupa*, a babe, girl, *pupilla*, a little babe, so called from the image seen in the eye.] The opening in the iris which admits rays of light to the internal refractive media of the eye.

Pu-tre-fac'tion. [L. *putris*, rotten, and *facere*, to make.] A species of decomposition taking place in dead organic matter under certain circumstances associated with the presence of an organism—*bacterium termo*.

Py-lo'rus. [Gr. πυλη, agate, and ουρος, a keeper.] The opening from the stomach to the duodenum, or first part of the small intestine.

Ra'di-us. [L. *radius*, a spoke, staff, or rod.] One of the bones of the forearm.

Ra'nine. [L. *rana*, a frog.] A name applied to an artery under the tongue. It is a continuation of the lingual artery. Relating to a frog.

Rar-e-fac'tion. [*Rarus*, rare, thin, and *facere*, to make.] A name applied to changes in atmosphere or gas by which the bulk is increased and the density diminished.

Rec'tum. [L. *rectus*, straight.] The last portion of the large intestine, so called because it was wrongly supposed to be straight.

Re-duc'tion. [From *re*, and *ducere*, *ductum*, to lead.] The act of restoring displaced parts to their normal position, as in fractures and dislocations.

Ren'net. [Gr. *gerinnen*, to coagulate.] A substance obtained from the abomasus or fourth stomach of the calf which has the power to coagulate the casein of milk.

Re-pro-duc'tion. [L. *re*, and *producere*, *productum*, to bring forth.] A function by which animals and plants reproduce their kind.

Re-sec'tion. [L. *re*, and *secare*, to cut off.] The operation of removing a part. A name generally applied to the removal of the extremities of long bones for diseases.

Res-pi-ra'tion. [L. *re*, and *spiro*, to take breath, *spirare*, to breathe.] A word used to denote both inspiration and expiration. The appropriation of oxygen by the tissues. The act of breathing.

Re-tic'u-lum. [*Rete*, a net.] The second stomach of ruminants. A delicate supporting network for glandular and nervous tissue, etc.

Rig'or. [L. *rigere*, to be stiff.] The severe chill of a fever.

Ru'mi-nant. [L. *ruminare*, to chew again.] An animal that chews the cud, or chews over again that which has been swallowed.

Sa'crum. [*Sacer*, sacred, holy.] The triangular bone which forms the posterior boundary of the pelvis. A part of the vertebral column. So called by the ancients because it was offered in sacrifice, or because it aided in protecting the genital organs, which were considered sacred parts.

Sag'it-tal. [L. *sagitta*, an arrow,] Arrow-shaped. The suture between the two parietal bones.

Sa-li'va. [F. *salive.*] The digestive fluid of the mouth. Spittle.

Sar'code. [Gr. σαρκος, flesh.] A term used to denote the living matter of plants and animals.

Sar-co-lem'ma. [*Sarco*, flesh, and λεμμα, a coat.] The membrane that surrounds a muscular fibre.

Scap'u-la. [L. *scapula*, the shoulder-blade.] The large triangular bone at the posterior part of the shoulder, articulating with the clavicle and humerus.

Scler-ot'ic. [Gr. σκληρος, hard.] The hard white tunic of the eye.

Se-ba'ce-ous. [L. *sebum*, suet, fat.] Fatty, of the nature of suet.

Se-cre'tion. [L. *secernere*, *secretum*, to separate.] Something separated from the blood, or manufactured in a gland to be used again for nutritive purposes, as milk, saliva, gastric juice, etc.

Semi-lu'nar. [*Semi*, half, and *luna*, the moon.] Half-moon-shaped.

Sen-si-bil'ity. [L. *sentire*, *sensum*, to feel.] Having the power to feel. The consciousness of receiving impressions through the senses.

Sep'tum. [L. *sepio*, *septum*, to fence in.] A partition between cavities.

Ser-ra'ted. [L. *serra*, a saw.] Having rough processes resembling saw-teeth.

Se'rum. [Whey, from *serus*, late, left after butter and cheese are separated from milk.] The liquid part of the blood bereft of its fibrin.

Skel'e-ton. [Gr. *skello*, to dry.] The bony framework of the body.

Som-nam'bu-list. [L. *somnus*, sleep, and *ambulare*, *ambulatum*, to walk.] One who walks while asleep.

So-por-if'ic. [L. *sopor*, a heavy sleep, and *facere*, to make.] A drug, medicine, or influence that induces sleep.

Sphe'noid. [Gr. σφην, a wedge, and ειδος, resemblance.] Shaped like a wedge. The name of a bone at the base of the skull.

Spi'nal cord. [L. *spina*, a thorn or spine, and *chorda*, a string.] The nervous prolongation of the brain which is contained in the spinal canal.

Spir'it. [L. *spirare*, to breathe.] Life, breath. The disembodied soul. Meaning or intention. A name also applied to all distilled liquids, especially those containing much alcohol, as brandy, rum, whiskey; arack, made in India from rice and the fermented juice of the palm; araki, made by the Egyptians from dates; araka, made by the Tartars from koumis or fermented mare's milk.

Sta'pes. [L. *sto*, to stand, and *pes*, a foot.] A stirrup. The name of the stirrup-shaped bone or ossicle of the middle ear.

Ster'num. [Gr. στέρνον, the breast, ατερρος, solid.] The breast-bone. A flat bone situated in the anterior part of the chest, to which some of the costal cartilages are attached.

Stim'u-lant. [L. *stimulare*, to goad.] A substance which whips into activity the various tissues of the body without furnishing food to replace the loss occasioned by the increased work. Alcohol is such a stimulant.

Stom'ach. The most dilated portion of the alimentary canal.

Sty-loid. [Gr. στυλος, a style or peg, and ειδος, resemblance.] Shaped like a style or pin. A process of the temporal bone.

Suf-fo-ca'tion. [L. *suffocare*, *suffocatum*, to stop the breath.] Smothering, strangling. Death from arrested or impeded oxidation of the blood.

Sys'tole. [From *sys*, and στελλω, to contract.] The contraction of the heart, generally applied to the contraction of the ventricles.

Tar'sus. The posterior portion of the foot.

Teg'u-men. [L. *tegere*, *tectum*, to cover.] The integument or covering of the body.

Tem'po-ral. [*Tempus*, time.] The name of one of the bones situated at the side and base of the cranium, which contains the important organs of hearing.

Ten'don. [Gr. from τεινω, to stretch.] A

name applied to the white cords of fibrous connective tissue which attach muscles to bones. Sometimes called leaders.

Tes'ti-cle. [L. *testis*, a witness.] The glandular organs, situated in the scrotum, which furnish the male elements of reproduction.

Text'ure. [L. *texere*, *textum*, to weave.] The arrangement of tissues in the formation of organs.

Tho'rax. [Gr. a coat of mail; a cuirass.] The supra-abdominal cavity which contains the organs of circulation and respiration.

Thy'roid. [Gr. θυρεος, a shield, and ειδος, resemblance.] The shape of a shield. The largest cartilage of the larynx, which forms the prominence called Adam's apple, (*pomum Adami*).

Tib'i-a. [A flute or pipe.] The large bone of the leg.

To-bac'co. [From *tabacos*, the Indian or Caribbean name of the pipe in which it was smoked.] A native American plant of the genus *Nicotiana*. Used in medicine as an emetic, cathartic, narcotic, and sedative. Considered by some a luxury when used in smoking, chewing, and as snuff.

Tor'pid. [L. *torpeo*, to be sluggish.] Stupid. Inactive.

Tor'u-la cer-e-vis'i-æ. [L. *torus*, a knot.] The yeast-plant. A small plant allied to the class *Schizomycetes* (from *split* and *cells*. They reproduce by budding or by internal cell-division.)

Tour'ni-quet. [F. *tourner*, to turn.] A surgical instrument used to arrest the flow of blood in a large vessel. In the form of a simple string or fillet it was used by the old Roman surgeons as early as the second century by applying it around the limb during amputation. The great French surgeon Morel increased its efficacy in 1674 by introducing a stick under it by which it could be tightened; following this, came the screw tourniquet, invented by the French surgeon Petit in 1718, which, with some modifications and improvements, is the instrument used at the present time.

Tox-ic. [*Toxicus*, poison.] Poisonous.

Tra-bec'u-la. [Dim. of *trabs*, *trabis*, a beam.] A delicate band of connective tissue or of bone.

Tra'che-a. [Gr. rough, also air and to keep.] The tube which conveys air to the lungs. The windpipe.

Trans-for-ma'tion. [L. *trans*, and *forma*, form.] The act of changing shape or form. Also of structure.

Trem'or. [L. *tremere*, to tremble.] A weak muscular or nervous condition characterized by slight shaking or agitation of the body or some of its parts.

Tri-chi'na spi-ra'lis. [Gr. hair, and spiral.] A small nematoid worm or entozoon, infecting the muscular and other tissues of the human body. Derived from eating pork not thoroughly cooked.

Tri-gem'i-ni. [*Tri*, and *geminus*, double, threefold.] A name applied to the fifth pair of cranial nerves, which divides into three branches, the ophthalmic, superior, and inferior maxillary.

Tu'ber-cle. [L. *tuber*, a bulb.] A small protuberance or lump.

Tur'bin-a-ted. [L. *turben*, a top.] Twisted. The thin scrolls of bone situated in the nasal fossæ.

Tym'pa-num. [Gr. τυμπανον, a drum.] A name given to the middle ear from its fancied resemblance to a drum.

Ul'na. The large bone of the forearm which forms the prominence of the elbow.

Um-bil'i-cus. [L. *umbo*, a button.] The navel.

Un'ci-form. [*Uncus*, a hook, and *forma*, shape.] Shaped like a hook. The last bone in the second row of the carpus.

U'rea. [From *uron*, urine.] An effete poisonous matter separated from the blood by the kidneys.

U'vu-la. [L. dim. of *uva*, a grape.] A fleshy appendix of the soft palate.

Vac-ci-na'tion. [*Vacca*, a cow.] The

operation of introducing human or bovine virus under the cuticle, to fortify the system against the ravages of smallpox.

Valves. [L. *valvæ*, folding doors, from *valvo*, to fold up.] Membranous curtains found in vessels of the body to prevent the regurgitation of the liquids.

Var-i'o-la. [L. *varius*, spotted, *vari*, pimple.] Smallpox.

Vas'cu-lar. [L. *vasculum*, a little vessel.] Containing vessels.

Ve'hi-cle. [L. *vehere*, to carry.] Anything which bears, carries, or transmits.

Ven'om-ous. [F. *venin*, poison.] Poisonous.

Ven-ti-la'tion. [L. *ventilare*, *ventilatum*, to fan.] The act of changing air in crowded rooms, hospitals, etc.

Ven'tral. [L. *venter*, the belly.] Relating to the abdomen.

Ven'tri-cle. [L. dim. of *venter*.] A small cavity. Generally applied to the cavities of the heart, brain, etc.

Ver'mi-form. [L. *vermis*, a worm, and *forma*, form.] Resembling a worm.

Ver'te-bræ. [L. *vertere*, to turn.] The segments of the spinal column.

Ves'i-cle. [L. dim. of *vesica*, a bladder.] A small pouch or bladder.

Ves'ti-bule. [L. *vestis*, to clothe.] An entrance. A cavity of the internal ear between the cochlea in front and the semicircular canals behind, communicating with both.

Vil'li. [L. *villus*, a tuft of hair.] Little processes found on the mucous membrane of the small intestine.

Vis'ion. [L. *videre*, *visum*, to see.] The act of seeing.

Vi'tal. [L. *vita*, life.] Relating to life.

Voice. [L. *vocare*, to call.] Sounds made by the vibration of the inferior vocal cords, in obedience to the passage of air over them.

Vo'mer. [L. *vomeris*, a ploughshare.] The name of the bone helping to form the septum nasi. So called on account of its shape.

Vom'it-ing. [L. *vomere*, *vomitum*, to cast up.] The act of ejecting the contents of the stomach by the mouth.

Walk'ing. [Sax. *wealcan*, to walk. A variety of animal locomotion.

Wort. [F. *moût de la bière*.] An infusion of malt used in the manufacture of beer.

Wrin'kle. A furrow or fold in the skin.

Wrist. [Sax. to wrest.] The carpus.

Xi'phoid. [*Xipho*, sword, and ειδος, resemblance.] Sword-shaped. The lowermost piece of the sternum.

Yeast. [Sax. storm or stormy.] A ferment used in making bread, beer, etc. It generates carbonic acid gas.

Zyg'o-ma. [Gr. a yoke.] A process of the temporal bone.

Zy-mot'ic. [Gr. zyma, ferment.] Relating to fermentation.

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